Toward Effective Common Operating Policies for Medical Items in Ongoing Humanitarian Operations – The Science and Art of Segmentation – A Case Study

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Abstract

Ongoing humanitarian operations can suffer from the lack of medical item availability. The central problem thus becomes how to ensure the right item in the right place at the right time while maintaining appropriate costs. By means of a case study, this research grouped items by various item characteristics and assigned each group a common operating policy. The results of such item segmentation, and the application of common operating policies, was a theoretical increase over the current rule of thumb, single operating policy by 22% in average expected item availability and a decrease in total costs of 2-8%. Yet, similar results were achieved without segmentation. The major conclusion is that consideration of demand variability as a means to achieve greater item availability is key. The determination of appropriate costs becomes a transparent one for the decision-maker. More generally, this approach facilitates the comparison of various inventory management scenarios and the assumption of informed levels of risk.

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1.0 Introduction

The magnitude of humanitarian relief operations continues to grow (UN, 2017) and with it the importance of logistics and supply chain management. Via a case study, this thesis examined how the inventory management of medical items at a field-level dispensary could move toward more effective common operating policies. Specifically, this thesis examined the policies of “when” and “how much” medical items could be ordered with reference to “segments” or groups of “similar” medical items. Neither a unique solution nor a theoretical treatise, this research was undertaken in the spirit of what has been termed “action research” (AR) (Jahre, Ergun, Goentzel, 2015). This AR approach seeks practical action and simultaneously contributes to academic theory. In this way the research undertaken was for both practitioner and academic.

1.1 Problem Description

A project-specific 2017 assessment concluded that 29% of consumable items where either in rupture or at risk of rupture, while 58% of consumable items were in overstock (Organization, 2017b). Unfortunately, this stock situation may be all too common for the “Organization” in question. It has been estimated that 60% of product forecasts in the Organization result in stockout or overstock (Organization, 2017a). If so, the stock situation in this case study, and more generally for the Organization, would seem to be at odds with the stated overall supply chain goal that “quality and service correspond to the needs of humanitarian operations, ‘whilst guaranteeing appropriate costs’ ” (Organization, 2017b).

The problem thus became how to ensure the right medical item, in the right quantity, at the right time while guaranteeing appropriate costs. As Kraljic notes (1983) “the greater the
uncertainty of...[the] physical availability of [those] items, the more important supply management becomes.”

1.2 Research Objective

The project under study had in place a “single” inventory policy approach: the inventory for all medical items was reviewed every four months, and if necessary, orders placed. As such, could segmentation, or the grouping of medical items with similar characteristics and tailored inventory polices for these segments, improve item availability in ongoing humanitarian operations while maintaining appropriate costs? To address the research objective, this thesis developed a segmentation approach and a method to estimate expected medical item availability as well as expected costs.

1.3 Research Scope

The scope of this research was consumable medical items of a medical dispensary at field level (Figure 1.3.1). The upstream partner was the “Coordination”; downstream partners were the “consumption units,” those who provide medical items to the beneficiaries. The project is that of an international, humanitarian aid organization, referred to as the “Organization” herein. The remainder of the thesis is organized as follows.

Section 2 examines the literature on segmentation, inventory policies and humanitarian supply chains. It assembles the theoretical underpinnings of the subsequent research.

Section 3 formulates the problem, provides a hypothesis, outlines the research steps, and presents the mathematical foundation to assess expected item availability, expected annual costs and the expected inventory investment.
Section 4 uses the assessed literature and developed methodology to analyze from the dispensary, identifies the key drivers of item availability and cost, develops a segmentation approach, and applies inventory policies.

Section 5 presents the results of this analysis by scenario—two unsegmented, three segmented.

Section 6 discusses these results in light of the safety factor employed, the variability encountered, and the transport modes used.

Section 7 concludes with five key insights, three challenges, and five proposed extensions.
Figure 1.3.1 Research Scope in the Organization's Supply Chain
2.0 Literature Review

So as to determine if segmentation and common operating polices could improve item availability in ongoing humanitarian operations, at an appropriate cost, the literature was reviewed. Segmentation literature was consulted so as to understand existing frameworks and the criteria by which items may be grouped. Inventory models, and the policies derived from them, were also reviewed. The specificity of humanitarian supply chains was also examined. This section therefore provides the foundation upon which the methodology was built. For the practitioner this literature review may be considered a primer. For the academic this review specifically notes the expected contributions of the thesis to academic theory.

2.1 Segmentation

In general terms, to segment is to divide into parts. In supply chain management, segmentation is a creative means by which items with similar characteristics have common supply chain requirements. A sufficient number of items should be present in a segment to warrant managing the items differently. According to Allain, Goentzel, Bates, and Durgavich (2010) the groupings should be pragmatic—that is, useful and easily communicated. Specifically, segmentation techniques determine which characteristics to use, the number of groups to create, and the boundary between the groups (van Kampen et al. 2012).

Much of the literature on segmentation may be categorized into two broad approaches based upon either the product or the customer/market. Although various approaches and numerous criteria exist for segmenting, van Kampen (2012) notes the Stock Keeping Unit (SKU) classification has not received sufficient academic attention given the implications of decision-making in this area. This is likely do to the fact that given the diversity of approaches, a unified approach is lacking. This sentiment was echoed by Alicke and Forsting in Protopappa-Sieke
(2017) who noted that the literature lacks a holistic approach to segmentation. The authors applied the McKinsey supply segmentation framework (Alicke and Forsting, 2017) to various case studies, but none of these case studies were in a humanitarian context. This concern is addressed in this thesis.

Fisher (1997) segments items based upon demand characteristics. Items with low demand uncertainty are termed “functional” and best-suited to an “efficient” supply chain strategy—one focused on cost. Items with high demand uncertainty are termed “innovative” and best-suited to a market responsive supply chain strategy—one focused on service.

Lee (2002) segments items based upon demand and supply characteristics. For Lee, supply characteristics, or supply processes, are either stable or evolving. For instance, items with low uncertainty in both demand and supply suggest an efficient supply chain in which nonvalue-added activities should be eliminated, scale economies should be pursued, optimization techniques should be deployed, and information linkages should be established. Items with low demand uncertainty but high supply uncertainty suggest a risk-hedging supply chain in which safety stock should both increase and be shared for key items, information should be shared, and goods should be transshipped. On the other hand, for Lee, items with high demand uncertainty and low supply uncertainty suggest a responsive supply chain strategy. In this case, one should be flexible to the changing needs of the customer, often through build-to-order and mass customization strategies. And finally, items with high uncertainty in both demand and supply suggest an agile supply chain that combines the risk-hedging and responsive strategies. This agile strategy is both responsive to customer needs and attentive to the risks of supply shortages and disruptions.
More specifically, for both Fisher and Lee an item is said to have high demand uncertainty if there is difficulty in forecasting, variable demand, a short selling season, high inventory cost, high profit margins, high product variety, low volumes per stock keeping unit, high stockout costs, and high obsolescence (Fisher, 1997). For Lee, the determinants of supply uncertainty are breakdowns, yields, quality problems, the number of supply sources, supplier reliability, process, capacity, changeover, flexibility, and lead time variability (Lee, 2002).

Christopher and Towill (2000) also segment based upon demand and supply characteristics. They use three product criteria: demand (stable or volatile), replenishment lead time (short or long), and type (standard or special). Standard products with stable demand and long replenishment lead times suggest a “lean” supply chain strategy in which forecasting is algorithmic, scheduling is level, and volumes are high. Standard products with stable demand and short replenishment lead times suggest a “continuous replenishment” strategy in which frequent deliveries are made. On the other hand, products with volatile demand and long replenishment lead times suggest a “postponement” supply chain strategy. In this case, one should use generic or modular inventory and delay the final configuration until the customer requirement is known. And finally, products with volatile demand and short replenishment lead times suggest an agile supply chain in which products are individualized to the customer and can be provided in arbitrary lot sizes (Christopher and Towill, 2002). Because each of these strategies could be adapted to either standard or special products, Christopher and Towill propose eight “pipeline” configurations. Alicke and Foresting (Protopappa-Sieke, ed. 2017) note that the authors later reduce the criteria to two dimensions: demand predictability and lead time.

Christopher and Towill (2000) also propose a five criteria framework to classify products: (D)uration of the Product Life Cycle, the time (W)indow for delivery, (V)olume, (V)ariety, and
(V)ariability. This is known as the DWV³. Combinations of these characteristics lead to a classification of the product as “high” or “low” and the application of a lean or agile strategy.

Godsell, Diefenbach, Clemmow, Towill, and Christopher (2011) develop a “practical means for considering both product and market characteristics to enable the development of a segmented supply chain strategy.” This “demand profiling” uses key product characteristics of the DWV³ approach (volume and variability) and actual customer demand for the product as classifiers. Products with low demand variability and high volume suggest a “lean” supply chain segment in which one should focus on low cost and minimize inventory buffers. On the other hand, products with high demand variability should use inventory buffers. “Filters” applied to the demand profile segment may address concerns such as margin, growth, and strategic alignment.

Lovell, Saw, and Stimson (2005) use additional factors to segment. The authors group these factors into “product,” “market,” “source,” and “geographic and commercial environment.” For instance, the product factors include life cycle, variety, type, and physical size/weight. The market factors include demand location/dispersion, demand level (throughput), demand variability, and service expectations. They develop an operational framework for supply chain segmentation that highlights the key supply chain cost drivers (manufacturing, primary transport, facilities, secondary transport, inventory) and “the importance of product value density, throughput volume, and product availability.”

Pareto Analysis is a classic means of categorizing products (Simichi-Levi et al. 2008). Also known as “ABC” analysis, it is based upon the observation that often the top 20% or ‘A’ items account for 80% of, for example, expenditure. Management Health Services (MSH) (2012)
notes that item classification can help determine order frequency. For instance, "ordering class A items more often in smaller quantities should lead to a reduction in inventory holding costs."

Scholz-Reiter, Heger, Meinecke, and Bergmann (2012) have expanded this classic ABC analysis. The authors classify items according to "fluctuations in consumption." The demand coefficient of variation (CV) is used to segment because it allows various demand distributions to be standardized and compared. Mathematically, the CV is the standard deviation of the demand divided by the average demand.

\[ CV = \frac{\sigma}{\mu} \]  

(2.1.1)

The authors specify three ranges for the CV as "X", "Y" and "Z." Items with rather constant consumption and rare fluctuations are denoted X and have a CV <0.5. Items with stronger fluctuations (often associated with trends or seasonality) are denoted Y and have a CV which ranges between 0.5 and 1. Items with completely irregular consumption are termed Z and have a CV >1. This ABC-XYZ classification has been extended even further. In addition to historical consumption, data demand forecasts are also included. In some cases, this has led to quantifiably better forecasting outcomes (Scholz-Reiter et al. 2012).

2.2 Inventory Policies

At its most basic, an inventory policy answers two questions: when and how much to order. Inventory policies may be "rules of thumb" or the result of inventory models. Aspects of a rule of thumb inventory policy might be "order three months’ worth of product, plus 20%, when two months of stock is left."

More generally, Simchi-Levi (2008) defines inventory policy as the strategy, approach, or set of techniques to determine how to manage inventory. The author notes six general characteristics of the supply chain to take into account: customer demand, replenishment lead
time, the number of different products, the length of the planning horizon, costs, including order cost and inventory holding cost, and service level requirements. Of particular note, the author indicates that taxes, insurance, maintenance, obsolescence (emphasis added by the author), and opportunity costs form the basis of the inventory holding cost.

Inventory models used to derive inventory policies can focus on multiple stages or a single stage of the supply chain. "Multiechelon" models examine multiple stages and attempt to determine the optimal inventory policies across the supply chain (Graves et al. 2000). Single-stage models range from those in which inventory may only be ordered once, ordered continuously, or ordered periodically. For instance, in the event that a product has a short lifecycle and one may order only once at the beginning of a period, the inventory policy may be derived from the notion that the order quantity should balance the cost of having too little of the item with the cost of having too much. Alternatively, if one is able to continuously review the inventory level, one might order when the stock level on hand can still cover the average demand over the expected time to receive the item, or "lead time." With such a continuous review approach one might order a quantity that balances the ordering cost and the cost to keep the item in stock before it is consumed, or holding cost. Finally, if one reviews the inventory level only periodically, one might order, say, at set intervals of four months. Under such a periodic review the quantity ordered might be the expected average demand until the next time the stock level is reviewed, also considering the expected average demand over the time to receive the item (lead time). These three inventory management models have been formalized in the literature. They are known as the single period, the continuous review, and the periodic review models (Simchi-Levi et al. 2008)
More formally, the single period model is a probabilistic or stochastic model. It is designed to deal with the uncertainty of demand. An inventory policy is established from the ratio of the overage and underage costs of the item. This critical ratio (CR), or critical fractile, is then used to assess that point on a known distribution of demand, where having too little of the item costs the same as having too much. Mathematically it is the cost of shortage \( c_s \) over the cost of shortage plus the cost of excess \( c_e \)

\[
CR = \frac{c_s}{c_s + c_e} \quad \text{(2.2.1)}
\]

One orders the quantity \( Q \) associated with this point before the actual demand for the item occurs or materializes.

Continuous review inventory models, or ones in which the stock level is continuously monitored, can establish various inventory policies (McGuire, 2015). Three continuous review models are of particular interest. An “s-Q” policy has a reorder level and a fixed order quantity. Thus an \((s,Q)\) inventory policy states that a quantity \( Q \) is ordered when the inventory position is less than a predetermined stock level \( s \). “Inventory position” is the inventory on hand plus the inventory on order (minus back orders and inventory already committed for distribution). This remaining stock level should be sufficient to cover the average demand (and a portion of the demand variability) over the lead time. ‘\( Q \)’ is often derived from the Economic Order Quantity (EOQ) calculation.

\[
Q = \sqrt{\frac{2c_t D}{c_e}} \quad \text{(2.2.2)}
\]

Where \( c_t \) is the ordering cost of the transaction, \( D \) is the demand, and \( c_e \) is the cost of excess. This policy is also known as “order point, order quantity.”

An “s,S” policy also has a reorder level, but instead of a fixed order quantity, one orders “up to” a predetermined level. Thus an \((s,S)\) inventory policy states that when the inventory
position reaches the reorder level, a quantity equal to the difference between the inventory position and the order-up-to level is ordered. It has shown that in the absence of fixed order costs, the (s,S) policy is optimal (Simchi-Levi, 2008).

An “S” inventory policy has an order-up-to-level and reorders are placed when an item is taken from stock. Thus an (S-1,S) inventory policy states that a quantity is ordered to bring the inventory position back up to a predetermined level each time an item is taken from stock. The level (S) has two components: the expected demand over the lead time and the standard deviation of demand over lead time multiplied by a safety factor. This policy is known as the “base stock policy,” or “one-for-one” policy (McGuire, 2015).

With the aforementioned single-stage, continuous review inventory policies stock levels are continuously monitored. Periodic review policies, on the other hand, assess the stock level at fixed intervals. The “review periods” for a periodic review policy vary and could be, for instance, a week, a month, or every six months. Three periodic review models are of particular interest. Bossert notes (2007) that the order cycle is that time between consecutive orders or consecutive replenishments, or simply the review period.

An “R-s-S” policy has a review period (R), reorder level (s) and an order-up-to level (S). Thus an (R,s,S) inventory policy states that at regular intervals (R) if the inventory position (stock on hand + pipeline - backorders) is less than the stock level (s) a quantity is ordered to bring the inventory position back up to a predetermined level (S). If the review period is quite short, such as daily, the stock level (s) in the periodic review may be approximated as the number of items sufficient to cover the average demand over the lead time (and a portion of the variability of demand and lead time) (Simchi-Levi 2008). The predetermined level (S) is approximated as the stock level (s) plus the quantity derived from the EOQ (see Equation 2.2.2).
An "R,S minus 1,S" policy has a review period (R), a reorder level (S-1) and an order-up-to-level (S). Thus an (R,S-1,S) inventory policy states that at regular intervals (R) if the inventory position is less than a predetermined level (S) a quantity is ordered to bring the inventory position back up to that predetermined level (S). The order quantity made at the review period is equal to the total amount consumed since the last review period (Willems, 2016). As before, this predetermined level "S" is called the base-stock level. The level (S) again has two components, though different than before: the expected demand over the review period and lead time, plus the standard deviation of demand over the review period and lead time, multiplied by a safety factor. This policy is also known as the (R,S) policy, omitting "S-1".

Within the domain of multiechelon inventory models, Graves and Willems (2000) propose a single-stage model as the building block for their multistage model. Although the model was developed with manufacturing in mind, it is generally applicable to humanitarian supply chains. For the authors, a 'stage' represents a 'major processing function' of the supply chain. Each stage is assumed to have a known deterministic production lead time. This lead time is the time from when all the inputs to the stage are available until production is completed and demand is ready to be served. Also included in this stage lead time is any transportation time to put the finished goods into inventory. Graves and Willems assume that lead time is not affected by the size of the order. In other words, there are no capacity constraints. More formally, the net replenishment time (τ) equals

\[ SL + T + r - S \]

where \( SL \) is the incoming service time, \( T \) is the stage time, \( r \) is the review period, and \( S \) is the outgoing service time (Willems, 2016). Note that with the use of the model for single-stage
calculations, mathematically the incoming service time, $SI$, can be set to zero while the stage time $T$ includes the lead time to order, procure, transport, and receive the items.

Graves and Willems (2000) assume that a stage operates with a periodic review, base stock replenishment policy (a special case of the $(R,S)$ policy) and all stages share a common review period. In each period the observed demand is placed as an order on the upstream stage. This observed demand is the sum of the orders placed by the immediate successors of the stage. Importantly, they assume that demand at each stage is “bounded.” The authors presume that there is an upper bound “on demand over varying horizons for each item” (Graves and Willems, 2000). By this, they believe that it is a management decision to have safety stock on hand to cover up to a certain variability of demand. Beyond this threshold a manager decides how to handle this unexpected demand, such as expediting. The determination of this threshold is the safety factor ($k$) and indicates how often the manager will resort to other tactics to handle the demand variability. The authors also assume that each stage quotes a guaranteed service time and that within this service time 100% service is provided.

For inventory models, the costs related to purchasing, ordering, holding, and stockout may be derived from the general total cost equation. More formally,

$$TC(Q) = cD + c_t \left( \frac{D}{Q} \right) + c_e \left( \frac{Q}{2} + k\sigma_D + DL \right) + c_s E[US]$$

(2.2.4)

where the total cost $TC$ is a function of the item quantity $Q$, $cD$ is the purchasing cost ($c$ as the unit cost per item and $D$ as the demand); $c_t \left( \frac{D}{Q} \right)$ is the ordering cost ($c_t$ as the cost per transaction and $\frac{D}{Q}$ as the demand $D$ over the order quantity $Q$, which results in the number of transactions);
$c_e \left( \frac{Q}{2} + k \sigma_{DL} + DL \right)$ are the holding costs ($c_e$ as the cost of excess, $\frac{Q}{2}$ as the average amount of cycle stock, $k \sigma_{DL}$ as the safety stock and $DL$ as the pipeline stock); and finally $c_s E[\text{Units Short}]$ are the stockout costs ($c_s$ as the cost per item short and $E[US]$ as the expected units short, or the average demand beyond the items on hand).

2.3 Humanitarian Supply Chains

Segmentation in public health supply chains has been addressed by Allain, Goentzel, Bates, and Durgavitch (2010). The authors note that “each group can be managed best according to what its characteristics require. This can lead to more efficient supply chains that function effectively, improving product availability at a lower cost.” John Snow, Inc. (JSI) (2017) concurs: “procuring, storing, and delivering all these products in the exact same way does not make sense and will not achieve 100% availability...Segmentation can help.” The JSI Supply Chain Manager’s Handbook (2017) specifically notes that “inventory policies should be set at each level of the supply chain, for each type of facility, and for different commodities or commodity segments, as needed.” (emphasis added by author)

The need for such effective inventory policies in humanitarian supply chains is of particular importance. This is because errors in inventory control for humanitarian organizations often take a long time to correct due to long lead times (McGuire, 2015). Such long lead times also account for the fact that periodic review policies are often considered the most appropriate form of inventory control in humanitarian operations (McGuire, 2015). Yet, avoiding such errors is not trivial. For instance, van Wassenhove (2012) notes that humanitarian logistics faces inventory problems under high uncertainty.

Mora-Ochomogo (2106) notes that inventory management in humanitarian operations is a field developed by the academy in the last ten years. The authors call for “more models
considering multiple different items in inventory.” In this regard, van Wassenhove (2012) suggests that if the context is understood there is no reason that practices which have proven valuable from operational research could not be applied to humanitarian operations. Therefore, the adaptation and application of the Graves and Willems Guaranteed Service Time model (2000) to single-stage inventory management in humanitarian supply is of particular interest. The model assumes that there are no violations of the guaranteed service time and each stage provides 100% service to its customers—an apt desire for humanitarian supply chains. Additionally, the model assumes that some form of action will take place to ensure that all materialized demand is met beyond a service level set by management—again an apt desire for humanitarian supply chains. Bossert and Willems (2007) later extend the Guaranteed Service Time model to general review periods. A model such as this is likely to address what van Wassenhove (2012) refers to in humanitarian logistics as “a lack of available data for decision analysis.”

In humanitarian logistics, Kunz (2017) highlights that a number of papers identify a lack of work that links academic theory to practice. Kunz also notes that others have called for “a closer relationship between academia and practice.” Research conducted for this thesis addressed such concerns.
3.0 Methods

With the literature reviewed, a primary methodology was developed to answer the research question could segmentation and tailored inventory policies (or “operating polices”) improve item availability in ongoing humanitarian operations while maintaining appropriate costs. To that end, the problem description (Section 1.1) was extended to “problem formulation”. Five research steps were then established. Thus, a model was created by which inventory policies could be evaluated for expected item availability and expected cost. This section therefore provides for both the practitioner and the academic, the basis upon which the analysis (Section 4) was subsequently performed.

3.1 Formulate the Problem

As noted in Section 1.1, the problem too often is that the right medical item is not available in the right quantity and at the right time. A paramount concern for the Organization is the medical consequences to the beneficiaries which results from this lack of item availability. Secondly, inappropriate costs (as defined) are incurred from such lack of item availability, stockouts, and, conversely, overstock. The problem thus became how to ensure the right medical item, in the right quantity at the right time “whilst guaranteeing appropriate costs” (Organization, 2017b). The belief was that the current approach to medical item management may be too uniform—not incorrect per se, just incomplete, due to inherent uncertainties. The hypothesis was that fewer stockouts were to be expected for medical items, at the same time guaranteeing appropriate costs, when certain item availability and cost drivers were formally considered, segments developed, and an appropriate common operating policy applied.
3.2 Research

As Yin (1994) notes, case studies have the ability to describe a phenomenon, explain a phenomenon, or test the robustness and limits of a theory. All three were applied to various degrees in this thesis. For instance, one theory tested with reference to the case study data was that the expected lack of item availability and expected “inappropriate” costs resulted, in part, from policy decisions about when and how much to order, and the amount of safety stock to hold, if any. As mentioned in Section 1.3, this research focused on the medical items, certain availability and cost drivers, segments, and common operating policies within the context of a single medical dispensary at field level. More specifically, the research steps included:

1. **Obtain a list of medical items to stock.**
2. **Determine candidate drivers, key drivers and their respective values.**
3. **Group items into segments by key drivers.**
4. **Assign an inventory policy per segment.**
5. **Evaluate.**

For clarity, evaluations of the scenarios, inventory policies, segments, and drivers are discussed in Section 3.3. An in-depth discussion of the five research steps follows.

1. **Obtain a list of medical items to stock.**

   A list of 187 medical items was obtained from a “liste standard dispensaire MED” (dispensary standard medical list) of the project under study. This list was retrieved from the project’s Enterprise Resource Planning (ERP) software. Of the 187 consumable medical items,
136 items are categorized as (D)rugs, four categorized as Medical (E)quipment, and 47 as (S)upplies.

2. Determine candidate drivers, key drivers, and their respective values.

The term “driver” describes a characteristic which presumably affects a medical item’s availability and/or cost. This thesis focused on three types of candidate drivers (after discussion with both medical and supply personnel). First, “item” characteristics included consumable/nonconsumable, perishability, medical priority, handling requirements, value, physical size, and weight. Second, demand characteristics included quantity, variability, and service expectations. Finally, supply characteristics included lead time and its variability.

Not all candidate drivers were fully assessed. Qualitative judgement, based upon the literature review (see Section 2.1), stakeholder experience, and that data readily available, reduced this set of candidate drivers. Those drivers presumed to have the greatest impact on item availability and cost outcomes were selected for analysis (see Section 4.1). Although this type of selection follows the logic of Engineering Options Analysis (de Neufville, 2011), formal sensitivity analysis was not conducted on each candidate driver. Once the subset of seven drivers had been identified for analysis (demand variability, average monthly consumption, purchasing cost, item size, item weight, lead time, and lead time variability), relevant data was collected including that data available from the ERP product sheet. Expert judgement and managerial objectives were necessary to determine some parameters such as the expected service level, defined as the expected percentage of item availability during an order cycle (see Section 2.2). It was not clear from discussions with those in the Organization if, and how, a particular target service level had been set per medical item. For process simplicity and ease of comparison
during analysis, a service level of 95% was initially set for medical items. Demand data on average monthly consumption (AMC) was exported from the project ERP. Subsequently, certain intermediate variables were calculated such as the standard deviation of average monthly consumption (\( \sigma \)), the average monthly consumption value (\( \mu \)) and the average monthly consumption (demand) coefficient of variation (CV). Supply characteristics such as the expected lead time, actual lead time (in months) and transportation mode were provided, while the variability of lead time per item was calculated (standard deviation of lead time per item and its coefficient of variation).

3. Group items into segments by key drivers.

Numerous combinations of drivers could result in many groups, or segments. It was strongly suspected that the greater the number of segments, the greater the likely benefit in terms of service, and inventory related “appropriate” costs. Greater segmentation, however, may incur greater operational complexity. Therefore, the theoretical was balanced with the practical. Groups of medical items were thus created based upon the key drivers of monthly demand variability (as measured by the coefficient of variation), item physical size, and lead time. For a detailed discussion of the analysis necessary to achieve these segments, please see Analysis (Section 4.2).

4. Assign an inventory policy per segment

A wide range of inventory models were theoretically available (see Section 2.2). McGuire (2015) notes that periodic review models are well suited to humanitarian operations. Willems (2016) also notes that if one is trying to satisfy a specific service level, single-stage periodic
review models “work perfectly.” The thesis research scope focused on ongoing humanitarian operations; therefore, a periodic review, base stock inventory model was used to describe, assess, and analyze inventory policies given segments. Various review periods, service levels and lead times were also analyzed.

3.3 Evaluate

Once key drivers had been selected, segments created, inventory policies assigned, and scenarios created, five different scenarios were evaluated (Table 3.3.1). In two scenarios medical items remained unsegmented, though different methods of safety stock calculation were used. In the three other scenarios medical items were segmented, first based upon demand variability, subsequently by physical size, and finally lead time. The evaluation criteria for these scenarios were the expected item availability and the expected costs associated with the inventory policy.

More specifically, the evaluation took place via an adaptation of the single-stage Guaranteed Service Time model (Graves and Willems, 2000) (see Section 2.2). This model was adapted to assess each scenario’s expected item availability and the expected costs. The adapted model included the parameters of average monthly consumption (historic demand), forecasted monthly consumption (forecasted demand), per unit procurement cost, per unit transport cost, transport lead times, item unit weight (pack), item unit size, (pack) and the holding cost rate. Intermediate variables were added: the standard deviation of demand, the demand coefficient of variation, item unit weight (piece), item unit size (piece) cumulative procurement costs, expected inventory holding costs, the expected costs per items short, the expected annual costs, and the expected inventory investment costs. Service level (see Section 6.1), or the management
Scenario: base stock/single-stage; review period of 4 months; 4 month total lead time; holding rate (a) of 0.15; ocean transport

<table>
<thead>
<tr>
<th>1</th>
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<tbody>
<tr>
<td><strong>Scenario: base stock/single-stage; review period of 4 months; 4 month total lead time; holding rate (a) of 0.15; ocean transport</strong></td>
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<td><strong>Scenario:</strong></td>
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<tr>
<td><strong>rule of thumb:</strong> 2 months</td>
<td><strong>statistical assist - if demand variability CV 1.33:</strong> review period = 3 and transport by air with presumed lead time T = 3; safety stock based upon demand variability</td>
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<tr>
<td><strong>approach</strong></td>
<td><strong>statistical assist - safety stock based upon demand variability</strong></td>
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<td><strong>safety stock based on AMC</strong></td>
<td><strong>statistical assist - if demand variability CV 1.33 and if total sizes 1 m³:</strong> review period = 3 and transport by air with presumed lead time T = 3 and safety stock based upon demand variability</td>
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<tr>
<td><strong>segmentation</strong></td>
<td><strong>statistical assist - if demand variability CV 1.33 and if total sizes 1 m³:</strong> review period = 3 and transport by air with presumed lead time T = 1 and safety stock based upon demand variability</td>
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<tr>
<td><strong>common operating policy</strong></td>
<td><strong>statistical assist - if demand variability CV 1.33 and if total sizes 1 m³:</strong> review period = 3 and transport by air with presumed lead time T = 1 and safety stock based upon demand variability</td>
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Table 3.1.1 Comparison of Common Operating Policy Scenarios by Approach—Segmentation and Number of Policies
decision of the expected item availability during an order cycle, was established for all scenarios.

It was assumed that the frequency and size of past requests for the item followed a "normal" distribution if the average monthly consumption had been greater than ten units. In other words, it was assumed that there was an equal likelihood of a request being greater than the average as less than the average. Moreover, with the assumption of a "normal" distribution, it was further assumed that a future request was more likely to be closer to the average than further from it. On the other hand, if the average monthly consumption was less than ten units of demand it was assumed that the variability of demand was distributed unequally around the average, or mean. More formally, an asymmetric distribution of demand was assumed in which the mean equals the variance. This "Poisson" distribution is often used to model slow moving inventory (Simichi-Levi et al. 2008) such as those medical items in the case study with a reduced average monthly consumption. With both distributions of the demand, requests were assumed to be independent and identically distributed (i.i.d).

Therefore, for each scenario, every medical item had an expected item availability and an expected cost. A summary of the model follows:

**Decision variables** when and how much to order, how much safety stock, transport mode

**Parameters** – per unit procurement cost, per unit transport cost, transport lead times, annual holding rate, average monthly consumption (historic demand), forecasted monthly consumption (forecasted demand), item unit weight, item unit size

**Intermediate variables** – standard deviation of demand, the demand coefficient of variation, cumulative procurement costs, expected inventory holding costs, expected units short, cost per item short, expected annual costs, and the expected inventory investment costs.

**Objective** – item availability

**Constraints** – appropriate costs
More formally, with reference to the work of Graves and Willems (2000), the probability that a medical item would be available was based upon the size of the item’s safety stock and the likelihood that a request would exceed it. The safety stock size had been calculated based upon the demand variability, or “sigma” (\( \sigma \)), the net time it takes to replenish an item (in this case the review period \( (r) \) plus the lead time \( (T) \) which added together equals, “tau” \( (\tau) \), and the percentage of variability management hopes to cover (the safety factor, or ‘z’).

\[
z\sigma\sqrt{\tau} \tag{3.3.2}
\]

By the same logic, the service level for each item was the probability that the item was theoretically available when needed (one minus the probability of a stockout). The average expected service level for each scenario was then calculated. Mathematically, this was an unweighted sum of the item service levels divided by the number of items evaluated. Theoretically, the item service levels could have been given a weight so as to give added importance to particular medical item availability per scenario. This thesis, however, did not consider ‘medical priority’ and therefore used an unweighted sum of item service levels. Nonetheless, this established a comparable measure of expected item availability across scenarios.

In order to evaluate expected costs, per scenario, the thesis established the following expected annual cost equation with reference to the total cost equation (see Section 2.2):

\[
c_t \times \frac{12}{r} + \sum_{i=1}^{N} 12 \times C_i \times \frac{FMC_i}{AMC_i} \mu_i + \alpha_i c_i \left( z_i \sigma_i \sqrt{r_i} + \frac{\mu_i r}{2} + T_i \mu_i \right) + 12 \times (c_i + v_i) \sigma_i G(z_i) \tag{3.3.3}
\]

Specifically, the expected annual costs are the sum of the medical item purchase and variable transport costs (collectively termed procurement) \( (\sum_{i=1}^{N} 12 \times C_i \times \frac{FMC_i}{AMC_i} \mu_i) \), the cost to order the
items after each review period \( (c_t \times \frac{12}{r}) \), the cost to hold the item \( \alpha_i c_i \left( z_i \sigma_i \sqrt{\tau_i} + \frac{\mu_i r}{2} + T_i \mu_i \right) \),

and the cost to both purchase and expedite the expected units short \( (12 \times (c_i + \nu_i) \sigma_i G(z_i)) \) (Figure 3.3.4). An inventory holding cost is incurred to store, and if expired, dispose of the medical item (the obsolescence cost). For evaluation purposes, a constant annual holding cost rate was applied to all medical items \( (\alpha=15\%) \). The ordering cost was considered to be each review period’s fixed cost \( (c_t \times \frac{12}{r}) \) for ocean transport. The stockout cost in this formulation was the result of the cost incurred to purchase and expedite via air \( (c_i + \nu_i) \), in urgency, any medical item for which materialized demand exceeded the stock on hand. This theoretically ensured the right medical item in the right quantity at the right time.

Also considered was the expected inventory investment, a one-time cost to implement the proposed inventory policy:

\[
\sum_{i=1}^{N} c_i (z_i \sigma_i \sqrt{\tau_i} + \frac{\mu_i r}{2} + T_i \mu_i)
\]  

These possible inventory investment costs included—for all medical items—safety stock, \( (\sum_{i=1}^{N} c_i z_i \sigma_i \sqrt{\tau_i}) \), cycle stock \( (\sum_{i=1}^{N} c_i \frac{\mu_i r}{2}) \) and pipeline stock \( (\sum_{i=1}^{N} c_i T_i \mu_i) \). Such stocks theoretically may have been necessary to raise the level of existing inventory so as to meet a management decision of a specified service level going forward. The evaluation did not compare this theoretical, maximum, one-time inventory investment to the existing stock levels of the project in the case study. Rather, the evaluation compared the one-time, expected inventory
The annual cost equation is given by:

\[ c_t \cdot \frac{12}{r} + \sum_{i=1}^{N} 12 \cdot C_i \cdot \frac{FMC_i}{AMC_i} \mu_i + \alpha_i c_i \left( z_i \sigma_i \sqrt{\tau_i} + \frac{\mu_i r}{2} + T_i \mu_i \right) + 12 \cdot (c_i + v_i) \sigma_i G(z_i) \]

where:
- \( FMC_i \) is the forecasted monthly consumption (units/time)
- \( AMC_i \) is the average monthly consumption (units/time)
- \( \mu_i \) is the average demand (average monthly consumption) (units/time)
- \( \sigma_i \) is the standard deviation of demand (units/time)
- \( r \) is the review period (time)
- \( T \) is the stage time (lead time) (time)
- \( \tau_i \) is the net replenishment time (review period + stage time) (time)
- \( z_i \) is the safety factor (unitless)
- \( G(z_i) \) is the unit normal loss function (unitless)
- \( \alpha_i \) is the annual holding rate (€/inventory (€/time)
- \( c_t \) is the fixed cost of transport (€/order)
- \( c_i \) is the purchase cost (€/unit)
- \( v_i \) is the variable cost of transport (€/unit)
- \( C_i \) is the cumulative cost (purchase + variable transport) (€/unit)

**Figure 3.3.4 Annual Cost Equation—Type of Costs and Variable Definitions**
costs across scenarios assuming the entire inventory investment cost might be incurred.

The evaluation of each scenario’s average expected service level and expected annual costs included an assessment of each medical item’s demand and the variability of that demand. Given such inherent variability, it was desirable to be confident of these average estimations. Therefore, each scenario was simulated 2,000 times and a confidence interval was established around the simulated averages. Mathematically, the expected monthly demand for each medical item was established as a random variable based upon the average monthly consumption and the historic variability of demand. For those medical items with an average AMC>10, this variability of demand, along with the assumption of a normal demand distribution, mathematically allowed negative quantities to be randomly generated. In the event that the random variable of demand generated for an item was negative, the demand for that particular medical item, for that particular simulation event, was recorded as zero. For those medical items with an average AMC≤10 this need did not arise, as a binary approximation was used to generate random quantities from the poisson distribution which by its nature does not include the possibility of randomly generated negative numbers.

This approach, however, required later revision. In fact, the averages of the simulation results for all scenarios were consistently skewed. This resulted mathematically from truncating the normal distribution at zero without rescaling. As such the average was forced higher. The binomial distribution was instead used. Nonetheless even this approach to simulation had its limits, as it assumed that the sampled AMC was consistent over the net replenishment time (τ). As such, the primary focus of the methodology remained on the expectations.

In this way, each scenario was comparable by the criteria of expected item availability, expected annual cost, and expected inventory investment. In other words, this methodology
provided a means to evaluate common operating policies, applied to groups of medical items, segmented by key drivers, in ongoing humanitarian operations. This approach assessed the effectiveness of policies to ensure the right medical item, in the right quantity, at the right time "whilst guaranteeing appropriate costs" (Organization, 2017b).

Analysis details of this methodology follow in Section 4. The results may be found in Section 5.
4.0 Analysis

Having established a methodology to evaluate common operating policies in ongoing humanitarian operations the thesis analyzed the drivers of item availability and costs; segments, and review periods. This analysis revealed a 22% increase in expected item availability, in part, as a result of formally incorporating the demand variability driver into segments. There was less sensitivity to the actual segmentation boundary. For the practitioner this implies that inclusion of the demand variability driver may be more important than the specific boundary established. For the academic, this section provides methodological detail.

4.1 Drivers

Twelve candidate drivers were identified across three categories (see Section 3.2). Qualitative judgement, based upon the literature review (see Section 2.1), stakeholder experience, and data readily available, reduced this set of candidate drivers, hence the “art” of segmentation. For instance, the driver of “medical priority” did not become a key driver for this research. By way of explanation, during those meetings held in the Fall of 2017 various medical and supply stakeholders had expressed interest in the notion of “critical/noncritical” or the use of a classification system such as VEN, or “vital/essential/nonessential” (World Health Organization, 2016). Disagreements arose however, on the use and validity of such terms applied to medical items. It was noted that the ‘critical’ nature of an item may, in large part, be context dependent. Nor did the driver of perishability become a key driver for this research. Intuitively, highly perishable medical items or those with a short expiry date could benefit from tailored inventory policies. Nonetheless, modeling perishability by individual expiry dates per medical item became a non-trivial task and was abandoned. Finally, the driver of seasonality also did not become a key driver for this research. As evidenced by Neale and Willems (2015) seasonality is
clearly a concern, yet inclusion as a key driver would have required demand data beyond the eleven months available from the Enterprise Resource Planning (ERP) software.

Seven drivers were thus assessed per item: demand coefficient of variation (CV), average monthly consumption (AMC), purchase cost per month of the AMC (€), physical size of the AMC quantity (dm³), physical weight of the AMC quantity (kg), lead time in months, and the lead time coefficient of variation (CV-L). For the 187 medical items of the project under study, this represented hundreds of data points. These data points were initially characterized via summary statistics.

As previously noted, the demand coefficient of variation (CV) is a standardized measurement of dispersion/variability. More formally, it is the standard deviation of the demand divided by the mean of the demand (see Equation 2.1.1). In this way, the variability of demand could be compared across items. Upon initial inspection, these summary statistics revealed that the most common value (mode) for the demand coefficient of variation was zero, a curious result. This indicated that a number of medical items (44 to be exact) had no recorded demand in the ERP for the eleven months under study even though these items were listed on the project’s standard list. In a field setting, expert judgement combined with some form of analogous forecasting would have been used to assess likely future needs for these 44 items. Yet, in order to account for the influence of these 44 “zero quantity” items, these items were removed from the summary statistics. Only those items for which there had been recorded demand during the time period under study were included (Table 4.1.1).

As described in numerous inventory models (See Section 2.2), the size of the safety stock is calculated with reference to the standard deviation of demand (σ). All else being equal, the greater the standard deviation of demand, the larger the safety stock needed to cover the
### Table 4.1.1 Key Driver Summary Statistics for Medical Items (n=143)

<table>
<thead>
<tr>
<th></th>
<th>CV</th>
<th>AMC</th>
<th>monthly €</th>
<th>monthly dm³</th>
<th>kg</th>
<th>lead time in months</th>
<th>lead time standard deviation in months</th>
<th>lead time coefficient of variation</th>
<th>unit (piece) cost</th>
<th>unit (pack) weight</th>
<th>unit (pack) size m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>average</td>
<td>1,648</td>
<td>1125,957</td>
<td>62,195</td>
<td>23,412</td>
<td>7,434</td>
<td>1,922</td>
<td>0,484</td>
<td>0,242</td>
<td>1,541</td>
<td>1,578</td>
<td>0,006</td>
</tr>
<tr>
<td>standard deviation</td>
<td>0,625</td>
<td>3589,223</td>
<td>180,913</td>
<td>75,704</td>
<td>26,373</td>
<td>0,883</td>
<td>0,471</td>
<td>0,200</td>
<td>6,370</td>
<td>3,597</td>
<td>0,012</td>
</tr>
<tr>
<td>coefficient of variation</td>
<td>0,379</td>
<td>3,188</td>
<td>2,909</td>
<td>3,234</td>
<td>3,548</td>
<td>0,459</td>
<td>0,973</td>
<td>0,829</td>
<td>4,133</td>
<td>2,279</td>
<td>2,178</td>
</tr>
<tr>
<td>median</td>
<td>1,434</td>
<td>49,090</td>
<td>16,751</td>
<td>2,137</td>
<td>0,563</td>
<td>1,787</td>
<td>0,433</td>
<td>0,247</td>
<td>0,255</td>
<td>0,400</td>
<td>0,002</td>
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<td>mode</td>
<td>3,159</td>
<td>0,910</td>
<td>0,491</td>
<td>-</td>
<td>0,004</td>
<td>0,000</td>
<td>0,000</td>
<td>0,000</td>
<td>0,022</td>
<td>0,380</td>
<td>0,001</td>
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<td>upper 75%</td>
<td>1,893</td>
<td>636,360</td>
<td>55,026</td>
<td>11,224</td>
<td>3,425</td>
<td>2,214</td>
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<td>lower 25%</td>
<td>1,203</td>
<td>9,680</td>
<td>3,710</td>
<td>0,400</td>
<td>0,097</td>
<td>1,489</td>
<td>0,012</td>
<td>0,006</td>
<td>0,033</td>
<td>0,126</td>
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<td>max</td>
<td>3,194</td>
<td>31496,730</td>
<td>1606,333</td>
<td>595,638</td>
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<td>5,817</td>
<td>2,317</td>
<td>0,906</td>
<td>70,228</td>
<td>23,750</td>
<td>0,091</td>
</tr>
<tr>
<td>min</td>
<td>0,948</td>
<td>0,090</td>
<td>0,175</td>
<td>0,003</td>
<td>0,001</td>
<td>0,000</td>
<td>0,000</td>
<td>0,000</td>
<td>0,004</td>
<td>0,004</td>
<td>0,000</td>
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variability so as to meet a management established service level and thus achieve the desired expected item availability. Items with higher coefficients of variation therefore require higher numbers of items on hand relative to their own average demand. For this reason, the demand coefficient of variation (CV) was selected as a key driver for analysis.

A note on terminology: for this analysis, it was naively assumed that “demand” was synonymous with the Enterprise Resource Planning (ERP) records of stock depletion. In reality, this assumption was most likely not the case. For instance, if an item had been requested and were not available, the item would have “materialized demand” that was not “realized” nor necessarily reflected in the average monthly consumption figures of the ERP. It is worth noting, however, that both “expiries” and the reimbursement of loans were not considered in the average monthly consumption figures by the software. By convention, however, the terms “demand” and “consumption” were used when, in fact, the more accurate terms would be “recorded demand” and “depletion.” Medical items are “depleted” from the project dispensary and “consumed” by the beneficiaries.

Nonetheless, with regards to the demand coefficient of variation and the 143 medical items with recorded demand, average CV was 1.65 with a minimum of 0.95. As such, for Scholz-Reiter et al. (2012), all but four of the 143 items qualified as “completely irregular consumption,” those with a coefficient of variation greater than 1. By other standards, (MIT-CTL, 2017) 91 of the 143 medical items were considered “high variability” (CV ≥ 1.33). The remaining 52 were considered “moderate variability.” None, by either standard, could be considered stable or low variability items.

Intuitively, one of the greatest appropriate cost drivers would be transportation. In fact Lovell, Saw, and Stimson (2005) have classified both primary and secondary transport as key
supply chain cost drivers (see Section 2.1). As such, the transport costs per unit of medical item were derived via a regression analysis. For the origin-destination pair of the project under study, estimated consignment transport costs were solicited from the Organization intranet. Analysis yielded a fixed cost per shipment as well as per kilogram and per cubic meter variable costs for both air (adjusted $R^2=1$) and ocean (adjusted $R^2=0.91$). All coefficients were considered significant (air weight $p<0.01$ and size $p<0.0001$; fixed cost, weight, and size for ocean $p<0.0001$) except the fixed cost for air ($p=0.82$). Because the calculated figure was $36$ per air shipment, the variable’s non-inclusion in the expected annual cost equation was not considered problematic.

Blomberg and Gras note (2015) that if cargo has a volume (physical size) to weight ratio different than $1\text{m}^3:167\text{kg}$, air freight forwarders must pay the higher rate: either volume or weight. For this analysis the statistically significant regression coefficients for both physical size and weight for air transport were used, rather than one at the exclusion of the other. This could theoretically lead to an inconsistency between observed air transport rates and the model. Yet, as the regression approach was applied equally across all scenarios, comparison between scenarios remained possible.

Because transport mode costs were highly correlated to the physical size and weight of the medical items, both the driver of physical size ($\text{dm}^3$) and physical weight ($\text{kg}$) could theoretically factor into the analysis as key cost drivers.

4.2 Segments

As Protopappa-Sieke ed. (2017) note, the following guiding principles should be applied to the creation of segments: differentiation, value creation, mutual exclusivity, simplicity, universality, and “end-to-end.” These authors posit that ultimately, three to five segments and
corresponding strategies are considered “best practice.” Theoretically, a segment could be created simply based upon the variation within a single key driver. Recall Fisher’s (1997) choice of segmentation based upon a single criterion: demand uncertainty and the distinction of “low” and “high” (see Section 2.1). In van Kampen et al. (2012) terminology, Fisher determined which characteristic to use (demand uncertainty), the number of groups to create (2), and the boundary between the groups (high/low). In this research, it was not apparent *a priori* where to draw the boundary within a key driver. Much of the literature, like Fisher, often make the distinction “high” and “low,” yet these are relative terms. For the sake of analysis, such distinctions beg the question: Where should the boundary between segments be drawn?

To overcome this issue the following values per medical item were plotted on a parallel coordinates, multivariate graph (Figure 4.2.1): item ID, the demand coefficient of variation (CV), the average monthly consumption (AMC), the product value (excluding transportation costs) in euros (€), the physical size of the average monthly consumption (dm³), its weight (kg), lead time in months, (L) and lead time variability (as a coefficient of variation CV-L). (For confidentiality reasons the item codes have been blinded). As the name implies, this type of graph has multiple, parallel lines, or axes. Therefore, multiple drivers and their interrelationships were shown. Items were thus comparable within a driver, but also across drivers, as values were connected by a polyline. Patterns were therefore visually apparent.

In this way, the criterion of *differentiation* was at first assessed. Inherent delineations were sought, and candidate boundaries drawn. Although this practical technique established a point of departure for further segmentation analysis, it does have theoretical limits. For instance, variability within a driver may satisfy the segmentation criteria of differentiation
**Figure 4.2.1 Key Drivers—Parallel Coordinates, Multivariate Graph of Medical Items (n=187)**

- **ID**: medical item identifier
- **CV**: demand coefficient of variation
- **AMC**: average monthly consumption
- **€**: purchase cost of AMC (excluding transport costs)
- **dm³**: physical size of AMC
- **kg**: weight of the AMC
- **L**: lead time in months
- **CV-L**: lead time coefficient of variation
and mutual exclusivity but less so value creation. More specifically, with an understanding of Engineering Options Analysis (de Neufville, 2011) it may not be the differentiation and variability in the key drivers as inputs which is paramount, but rather the resulting outcomes. It is theoretically possible, therefore, that small variations in certain drivers have a disproportionate impact on the outcomes of expected item availability and expected costs.

With this in mind, the analysis was practical, empiric and iterative. As described in Section 3.3 the adapted Guaranteed Service Time model (Graves and Willems, 2000) was used to evaluate the visually identified, candidate segmentation boundaries. As an example of this process, a service level of 95% was set. Note however that in-line with the Guaranteed Service Time model (see Section 2.2), 100% of materialized demand was presumed to be addressed via alternatives such as expedited air transport—modeled as the cost per item short and the expected units short \( (12 \times (c_i + v_i) \sigma_i G(z_i)) \) (see Equation 3.3.3). With service established, the candidate segmentation boundary within the CV driver was iterated with an eye to changes in the expected costs. For instance, break points at CVs 1.3, 1.9 and 2.5 (Figure 4.2.1) appear to suggest natural group boundaries for the demand coefficient of variation. With the boundaries derived from this visual assessment, iterative analysis of the model confirmed the ‘reasonableness’ of segment boundaries with direct reference to the generated expected item availability and expected cost—hence the ‘science’ of segmentation.

A formal sensitivity analysis of the demand CV on the expected annual costs was also performed (Appendix B). This indicated, that under a certain set of conditions for review periods and transport lead times \( (r=3, T=4) \), incorporating the demand variability and varying the CV across its entire range of values (CV:0-3.5) for medical items \( (n=143) \) the expected annual costs ranged from \(~€160K\) to \(~€201K\). This range in expected annual costs was impacted by the initial
expected inventory investment. All things being equal, the higher the initial inventory investment, the lower the expected annual costs.

Because of this ultimately a \( CV \geq 1.33 \) was chosen as the segment boundary for the demand variability driver across scenarios as it represented current standards for 'high variability' items (see Section 2.1). This approach was influenced by Protopappa-Sieke, ed. (2017) criterion of simplicity and universality. By a similar logic physical size was chosen as the segmentation criteria rather than weight with a practical intention to limit the number of segments. In a similar way \( 1\text{m}^3 \) was selected as the segment boundary for the physical size (m³) driver, though its sensitivity on expected cost outcomes was less than that of the variability of demand as measured by the coefficient of variation.

The complete results of this iterative segmentation analysis and the associated scenarios are reported in Section 5.

4.3 Review Periods

A decision variable in the analysis model was “when to order.” This required a choice of review period. As noted in Section 2, the definition of a review period is the length of time between stock level reviews for an item. For scenarios three, four and five, two different review periods were analyzed: three months and four months. Four months corresponded to the Organization’s accepted practice for the project in this case study.

As reviews become more frequent, a “periodic review” approaches a “continuous review” (see Section 2.2). Theoretically one could continuously review stock levels and order each time the inventory level is reduced \((S-I)\) or when the inventory position is less than the stock level \((s)\) sufficient to cover the average demand (and a portion of the variability) over the time until the item arrives. This would have the advantage that for medical items with high demand variability,
continuous reviews would be more responsive with less stock than a periodic review. In practice, however, for ongoing humanitarian operations, continuous reviews were seen as impractical. To move toward the benefits of a continuous review inventory while still conducting a periodic review, however, in Scenarios 3, 4 and 5 the review period was shortened to three months \((r=3)\) for medical items with relatively higher demand variability \((CV\geq 1.33)\).

The complete results of this review period analysis and the associated scenarios are reported in Section 5.
5.0 Results

With the drivers, segments and review periods analyzed, this section reports the results of the model for the five scenarios with regards to inventory policies, expected item availability, and expected costs. These results indicate that segmentation and “common operating policies” based upon demand variability, physical size, review periods and transport modes can theoretically improve item availability in ongoing humanitarian operations—but segmentation is not a prerequisite for an increase in expected item availability at appropriate costs. For the practitioner, the results provide a concise way to compare expected item availability, its expected cost and, importantly the means by which to judge appropriate costs. In van Wassenhove’s (2012) terms, these results address “a lack of available data for decision analysis.” For the academic, this section highlights that material which results from the application of the methodology (see Section 3.2). Table 5.1.1 summarizes the analysis results.

5.1 Overview

Standard organizational policy is to create, based upon expert judgement, a ‘forecasted monthly consumption’ (FMC) for each item. In contrast to formal forecasting models such as Time Series Analysis or Exponential Smoothing (McGuire 2015) the Organization often employs a 10-20% addition to the average monthly consumption (AMC) as the FMC. Although not ideal from an academic perspective, this method was adopted for this case study in order to be consistent with current Organizational practice. Thus each scenario used a 15% increase of the AMC as the FMC for all of the medical items.
The table below presents a comparison of Common Operating Policy Scenarios expected item availability and expected costs with demand variability (CV) segment boundary at (CV≥ 1.33) and physical size (m³) segment boundary at (≤1m³).

<table>
<thead>
<tr>
<th>Scenario</th>
<th>AMC</th>
<th>number of items</th>
<th>expected annual costs (€)</th>
<th>expected inventory investment (€)</th>
<th>expected annual costs + expected inventory investment (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>no</td>
<td>0.7762</td>
<td>212.416</td>
<td>212.416</td>
<td>212.416</td>
</tr>
<tr>
<td>2</td>
<td>no</td>
<td>0.9500</td>
<td>157.694</td>
<td>157.694</td>
<td>157.694</td>
</tr>
<tr>
<td>3</td>
<td>yes</td>
<td>0.9500</td>
<td>182.911</td>
<td>182.911</td>
<td>182.911</td>
</tr>
<tr>
<td>4</td>
<td>yes</td>
<td>0.9500</td>
<td>167.417</td>
<td>167.417</td>
<td>167.417</td>
</tr>
<tr>
<td>5</td>
<td>yes</td>
<td>0.9500</td>
<td>166.506</td>
<td>166.506</td>
<td>166.506</td>
</tr>
</tbody>
</table>

*Table 5.1.1 Comparison of Common Operating Policy Scenarios—Expected Item Availability and Expected Costs with Demand Variability (CV) segment boundary at (CV≥ 1.33) and physical size (m³) segment boundary at (≤1m³)*
5.2 Scenario 1: Unsegmented Rule of Thumb

This scenario represented current practice. Medical items remained unsegmented (except for restricted items, such as narcotics and cold chain which must be transported by air). For these medical items (n=143), the inventory policy for Scenario 1 was “every four months, add 15% to the average monthly consumption of the last six months, and order (four months of cycle stock + four months to cover lead time) of this forecasted monthly consumption, minus inventory on hand, minus inventory on order plus committed inventory. Transport by ocean.”

With this inventory policy, the average chance of an item being unavailable during the order cycle is ~22%. The average expected service level is ~78%. No items have an expected service level greater than or equal to 95%. This inventory policy resulted in expected annual costs of ~€212K. This included procurement costs (purchasing + transport) of ~€132K, inventory holding costs of ~€12K, and stockout costs (purchasing + air transport) of ~€68K. The expected inventory investment (one-time) was ~€82K. The sum of expected annual costs and the expected inventory investment was ~€294K.

5.3 Scenario 2: Unsegmented - Safety Stock Based Upon Demand Variability

In this scenario, medical items remain unsegmented (except for restricted items, such as narcotics and cold chain which must be transported by air). Consistent with Scenario 1, the average monthly consumption was adjusted upwards by 15% to arrive at the forecasted monthly consumption per item.

Therefore, for the medical items in the project under study, the inventory policy for Scenario 2 was “every four months, order (four months of cycle stock + four months to cover lead time, minus the inventory position) based upon the forecasted monthly consumption. Transport by ocean.”
With this inventory policy, the average expected chance of an item being unavailable during the order cycle is \(-5\%\). The average expected service level is \(95\%\). In fact, all items have an expected service level equal to \(95\%\) because the safety stock was calculated expressly to cover \(95\%\) of the previous variability of average monthly consumption (demand) during the order cycle. This inventory policy resulted in expected annual costs of \(-\€158K\). This included procurement costs (purchasing + transport) of \(-\€132K\), inventory holding costs of \(-\€17K\), and stockout costs (purchasing + air transport) of \(-\€8K\). The expected inventory investment (one-time) was \(-\€114K\). The sum of expected annual costs and the expected inventory investment was \(-\€271K\).

A key difference between Scenario 2 and Scenario 1 was that Scenario 2 based the calculation of safety stock upon the variability of demand, rather than a rule of thumb two months of average monthly consumption. A comparison of the results revealed that certain expected values were the same, such as annual procurement, investment in cycle stock, and investment in pipeline stock. Such similarities were coherent. With regards to annual procurement, the quantity of items purchased was based upon the same forecasts, and all items in both scenarios were transported by ocean. Similarly, the investment in cycle stock was identical because the review periods were equal to four months (\(r=4\)). By the same logic, the investment in pipeline stock was identical between Scenario 2 and 1 because the lead times were both equal to four months (\(T=4\)).

A comparison of the results also revealed that certain expected values were different, such as expected item availability, annual holding costs, annual stockout costs, and investment in safety stock. Such different results were also coherent. Expected item availability was based upon the amount of safety stock held, and Scenario 2 held more safety stock than Scenario 1.
Annual holding costs were less in Scenario 1 than Scenario 2 as Scenario 1, as noted, held less safety stock, and with less safety stock held, Scenario 1 also had greater stockout costs as a result of less initial safety stock investment.

5.4 Scenario 3: Segmented - Demand Coefficient of Variation

In this scenario, two segments were created based upon the demand coefficient of variation. Consistent with Scenario 1, the average monthly consumption was adjusted upwards by 15% to arrive at the forecasted monthly consumption per item.

Therefore, for the medical items in the project under study, there were two inventory policies for Scenario 3. For items with a demand coefficient of variation greater than or equal to 1.33 (CV ≥ 1.33) (n=91) “every three months, order (three months of cycle stock + three months to cover lead time, minus the inventory position) based upon the forecasted monthly consumption. Transport by air.” For items with a demand coefficient of variation less than 1.33 (CV < 1.33) (n=52) “every four months, order (four months of cycle stock + four months to cover lead time, minus the inventory position) based upon the forecasted monthly consumption. Transport by ocean.”

With this inventory policy, the average chance of an item being unavailable during the order cycle is ~5%. The average expected service level is 95%. As noted with Scenario 2, in fact, all items have an expected service level equal to 95% because the safety stock was calculated expressly to cover 95% of the previous variability of demand during the order cycle. This inventory policy resulted in expected annual costs of ~€183K. This included expected procurement costs (purchasing + transport) of ~€159K, expected inventory holding costs of ~€16K, and expected stockout costs (purchasing + air transport) of ~€8K. The expected
inventory investment (one-time) was ~€106K. The sum of expected annual costs and the expected inventory investment was ~€289K.

A key difference between Scenario 3 and Scenario 2 was that Scenario 3 had a shorter review period for those items with a coefficient of variation greater than 1.33 (CV≥1.33) (n=91), and such items were transported by air with a lead time of three months (T=3). A comparison of the results revealed that certain expected values were the same such as expected item availability and expected annual stockout cost. Such a similarity was coherent because the service level was the same between Scenario 3 and Scenario 2, and thus there was the same expectation of item availability during an order cycle. Conversely, there was the same average number of expected unavailable items, or stockouts.

A comparison of the results also revealed that certain expected values were different, such as annual procurement, annual holding costs, as well as the investments in safety, cycle and pipeline stock. Such different results were also coherent. Scenario 3 incurred higher annual procurement costs as air transport was used for high variability items (n=91), and air transport was more expensive than ocean. Annual holding costs were less in Scenario 3 than Scenario 2, as Scenario 3 held less stock due to a lead time reduced from four months to three for high variability items (n=91). This reduction in lead time (T=3) combined with a shorter review period (r=3), reduced investment in safety stock. Investment in cycle stock was reduced in Scenario 3 due to a shorter review period, while investment in pipeline stock was also reduced due to a shorter lead time.

5.5 Scenario 4: Segmented - Demand Coefficient of Variation, Physical Size

In this scenario, two segments were created based upon the demand coefficient of variation and the total size of the item’s forecasted monthly consumption over the net
replenishment time \( (r) \). Consistent with Scenario 1, the average monthly consumption was adjusted upwards by 15\% to arrive at the forecasted monthly consumption.

Therefore, for the medical items in the project under study, there were two inventory policies for Scenario 4. For items with a demand coefficient of variation greater than or equal to 1.33 \( (CV \geq 1.33) \) for which the total size of the item's forecasted monthly consumption over the net replenishment time was less than one cubic meter \( (\leq 1\text{m}^3) \) \( (n=88) \) “every three months, order (three months of cycle stock + three months to cover lead time, minus the inventory position) based upon the forecasted monthly consumption. Transport by air.” For all other items \( (n=55) \) “every four months, order (four months of cycle stock + four months to cover lead time minus the inventory position) based upon the forecasted monthly consumption. Transport by ocean.”

With this inventory policy, the average chance of an item being unavailable during the order cycle is \~5\%. The average expected service level is 95\%. Again, as noted in the previous scenario, all items have an expected service level equal to 95\% because the safety stock was calculated expressly to cover 95\% of the previous variability of demand during the order cycle. This inventory policy resulted in expected annual costs of \~€167K. This included procurement costs (purchasing + transport) of \~€143K, inventory holding costs of \~€16K, and stockout costs (purchasing + air transport) of \~€8K. The expected inventory investment (one-time) was \~€109K. The sum of expected annual costs and the expected inventory investment was \~€276K.

A key difference between Scenario 4 and Scenario 3 was that in Scenario 4 only those high variability items that had a total size less than \( 1\text{m}^3 \) over the net replenishment time were transported by air \( (n=88) \). A comparison of the results revealed that certain expected values were the same such as expected item availability and expected annual stockout cost. Such a similarity was coherent. As the service level was the same between Scenario 4 and Scenario 3, there was
the same expectation of item availability during the order cycle. Conversely, there was the same average number of expected unavailable items, or stockouts.

A comparison of the results also revealed that certain expected values were different, such as annual procurement, annual holding costs, and the investments in safety, cycle, and pipeline stock. Such different results were also coherent. Scenario 4 incurred lower annual procurement costs because fewer high variability items were transported by air in Scenario 4 due to the 1m³ volume restriction \((n=88)\). Annual holding costs were greater in Scenario 4 than Scenario 3, because Scenario 4 held more stock due an increase in lead time from three months to four months for those same high variability items with a total size less than 1m³ over the net replenishment time \((n=3)\). The increased lead time \((T=4)\) due to ocean transport, combined with a longer review period \((r=4)\), increased investment in safety stock. Investment in cycle stock increased due to a longer review period \((T=4)\), while investment in pipeline stock increased due to a longer lead time for these items \((n=3)\) in Scenario 4.

5.6 Scenario 5: Segmented - Demand Coefficient of Variation, Physical Size, Lead Time

In this scenario, as in Scenario 4, segments were created based upon the demand coefficient of variation and the total size of the item’s forecasted monthly consumption over the net replenishment time. Consistent with Scenario 1, the average monthly consumption was adjusted upwards by 15% to arrive at the forecasted monthly consumption.

Therefore, for the medical items in the project under study, there were two inventory policies for Scenario 5. For items with a demand coefficient of variation greater than or equal to 1.33 \((CV \geq 1.33)\) for which the total size of the item’s forecasted monthly consumption over the net replenishment time was less than one cubic meter \((\leq 1m^3)\) \((n=88)\) “every three months, order (three months of cycle stock + one month to cover lead time, minus the inventory position) based
upon the forecasted monthly consumption. Transport by air.” Note that there was a presumed reduction in the air transport lead time from the current three months (T=3) to one month (T=1). For all other items (n=55) “every four months, order (four months of cycle stock + four months to cover lead time minus the inventory position) based upon the forecasted monthly consumption. Transport by ocean.”

With this inventory policy, the average chance of an item being unavailable during the order cycle is ~5%. The average expected service level is 95%. Again, as noted in the previous scenario, all items have an expected service level equal to 95% because the safety stock was calculated expressly to cover 95% of the previous variability of demand during the order cycle. This inventory policy resulted in expected annual costs of ~€167K. This included procurement costs (purchasing + transport) of ~€143K, inventory holding costs of ~€15K, and stockout costs (purchasing + air transport) of ~€8K. The expected inventory investment (one-time) was ~€103K. The sum of expected annual costs and the expected inventory investment was ~€269K.

A key difference between Scenario 5 and Scenario 4 was that in Scenario 5 those high variability items that had a total size less than 1m³ over the net replenishment time were transported by air (n=88) with a presumed lead time of one month (T=1) instead of three months as in Scenario 4. A comparison of the results revealed that certain expected values were the same such as expected item availability, annual procurement, annual stockout cost, and investment in cycle stock. Such similarities were coherent. With regards to annual procurement, the quantity of items purchased was based upon the same forecasts, and all items in both scenarios were transported by their respective transportation mode. As the service level was the same between Scenario 5 and Scenario 4, there was the same expectation of item availability. Conversely, there was the same average number of expected unavailable items, or stockouts.
A comparison of the results also revealed that certain expected values were different, such as annual holding cost, and the investments in safety and pipeline stock. Such different results were also coherent. Annual holding costs were less in Scenario 5 than Scenario 4, because Scenario 5 held less stock due to a reduction in presumed lead time from three months to one month for those air-transported, high variability items with a total size less than 1m³ over the net replenishment time (n=88). The presumed reduction in lead time (T=1) due to faster air transport decreased investment in safety stock. Investment in pipeline stock decreased due to a shorter lead time for these items (n=88) in Scenario 5.
6.0 **Discussion**

The results from Scenarios 3, 4 and 5 answered the research question that, in fact, segmentation could improve the expected item availability in ongoing humanitarian operations. Such results were achieved by the grouping of medical items with similar demand variability and physical size characteristics, and application of common operating polices. Yet these results also suggest that greater item availability may be achieved without recourse to segmentation, as evidenced by Scenario 2. The key point is that consideration of demand variability in this case study improves expected item availability. The question of appropriate cost, however, remained. Nonetheless, the evaluation was based upon the expectation of item availability and costs when tailored inventory policies were applied. These inventory policies were the result of an analysis of key drivers, segments and review periods. The analysis was made possible by the model adapted for the purpose, and informed by the literature. Yet, inherent in the model and the related inventory policies are the notions of a safety factor, variability, and transport mode. For the practitioner, this section discusses assumptions of risk and “inappropriate” costs, the need to formally consider variability, and the role of transport modes. For the academic, this section provides additional details and implications for the model and methodology.

6.1 **Safety Factor**

One contribution of this research is a methodology and model which presents the expected item availability and expected costs, based upon segmentation and applied inventory policies. Ultimately, however, cost appropriateness is a management decision. Yet with the types of results presented in Section 5 decision makers may clearly assess, weigh, and decide on the
balance between the primary objective of medical item availability and the secondary objective of appropriate costs.

The nature of this decision revolves around the concept of risk. In the context of the case study, and ongoing humanitarian operations for the Organization in general, it is presumed that 100% of the validated demand for the medical item should be met. The risk is not that the materialized, validated demand will go unmet; medical personnel envision that every creative effort will be taken by that supply chain which supports them. Such creative efforts often do ensure that the materialized, validated demand for the medical item is, in fact, met. As noted, the needs of the beneficiaries are paramount. Rather the risk is that these exceptional measures may incur inappropriate costs, such as emergency orders expedited via air transport.

The risk assumed is expressed via the safety factor. As noted in Sections 2.2, 3.3, and 4.2 the safety factor is present in many inventory models, and specifically in the model adapted for this research. Within this thesis, the safety factor has been alternately referred to as a driver, a decision set by management, and a parameter. As such, an explanation is necessary.

The safety factor is a driver of expected item availability and expected cost. A relatively lower safety factor incurs less safety stock, and less safety stock increases the likelihood of item unavailability (read stockout); while concomitantly it increases the cost later to receive the expedited medical item in urgency. The safety factor is a decision set by management in the sense that a coordinator decides what level of the aforementioned risk s/he wishes to assume—anticipate and pay for the medical item upfront, or pay more later and hope that it arrives in time. As such, the decision set by management becomes a parameter to the model.

For instance, in Scenario 1, per current Organization policy, a rule of thumb safety factor (safety factor in the practical, not mathematical, sense) was used. This safety factor was based
upon two months of average monthly consumption. For Scenarios 2 and 3 however, the safety factor was alternatively decided not as a rule of thumb but rather as a conscious choice to assume the risk that in any order cycle, there was the expectation that only 5% of the time the medical item might be unavailable. It would be necessary to take exceptional measures, such as emergency orders expedited via air transport 5% of the time for each medical item. The interactions of the safety factor \( z \) with the demand variability and the net replenishment time \( (z\sigma\sqrt{T}) \) play a key role in the determination of safety stock and the expectation of item availability (see Equation 3.3.2).

Within this thesis, the term safety factor has also been used interchangeably with “service level”. Again, an explanation is necessary. As noted in Section 2.2 the demand for an item can be characterized by an average and a variance, or standard deviation, around that average. Although the expectation is the ‘average demand’ in any month, it is possible (read nearly certain) that the demand which actually materializes varies from month to month. In this way, with such uncertainty, demand for an item is said to be a “random variable”. Hence a safety factor which assumes the risk that in any order cycle, there is the expectation that only 5% of the time the medical item might be unavailable is said to provide a cycle service level of 95%. Alternatively stated, a 95% service level represents the amount of variability management expects to cover with safety stock in an order cycle. With this research model all scenarios assumed that 100% of the materialized, validated needs would be served—95% for Scenarios 2, 3, 4 and 5 via anticipatory planning and inventory in the form of safety stock; 5% via exceptional measures, such as emergency orders expedited via air transport. Table 6.1.1 provides a comparison of scenarios with a cycle service level set to 99%.
Alternatively, the safety factor, and associated service level, could have been calculated rather than set. For instance, the amount of safety stock kept on-hand could be a balance between the effort/cost to expedite the item, against the effort/cost to hold the item another order cycle. This would address the variability of demand in the event that demand beyond the average materializes in the order cycle. With this approach, some percentage of the variability of demand would have been covered by proactive steps such as safety stock. The remaining variability of demand per medical item could have been covered reactively, via exceptional measures, such as emergency orders expedited via air transport.

More formally, the safety factor \((z)\) could be calculated with reference to a critical ratio (see Section 2.2). In fact, the cost of shortage would therefore become the effort/cost to expedite a medical item in the event that it is unavailable, while the cost of excess becomes the effort/cost to hold the medical item another order cycle. In this case, the critical ratio is a proxy for the cycle service level. As the cost of excess would be calculated with reference to the holding cost and this includes the cost of obsolescence, (see Section 2.2) the determination of a safety factor in this way could introduce the notion of perishability to the model, in a practical sense. Therefore, each medical item would become associated with its respective safety factor, and expected service level. The safety factor would be formally recognized in the model as a key driver of expected item availability and expected cost. By extension, the safety factor would thus become a means by which to segment and assign inventory policies.

Although this type of safety factor determination was not part of the analysis (see Section 4.1) nor impacted the results (see Sections 5.1–5.6) the model could accommodate such an
Scenario:
base stock/single-stage; (r)eview period of 4 months; 4 month (T)otal lead time; holding rate (a) of 0,15; ocean transport
rule of thumb: 2 months statistical assist
approach safety stock based on
AMC
segmentation
common operating policy
no
1
yes
2
average expected service level
0,7762
0,9900
0,9900
0,9900
0,9900
standard deviation of expected service level
0,0684
0,0100
0,0100
0,0000
0,0000
expected annual costs €
212.416 €
153.754 €
178.802 €
163.369 €
162.331
procurement (purchasing + transport) €
132.493 €
132.493 €
158.789 €
142.927 €
142.927
holding €
12.266 €
20.269 €
19.021 €
19.450 €
18.412
stockout €
67.658 €
993 €
993 €
993 €
993
expected inventory investment (one-time) €
81.772 €
135.125 €
126.806 €
129.664 €
122.744
safety stock €
20.443 €
73.796 €
69.955 €
71.338 €
68.423
cycle stock €
20.443 €
20.443 €
18.950 €
19.442 €
19.442
pipeline stock €
40.886 €
40.886 €
37.901 €
38.884 €
34.879
distribution of expected stockout events
% of items with expected service level greater than or equal to 95%
0%
100%
100%
100%
100%
Comparison with scenario one as baseline
average expected service level point difference
0
21
21
21
21
expected annual costs percent difference
0%
-28%
-16%
-23%
-24%
expected inventory investment (one-time) factor difference
1,0
1,7
1,6
1,5
1,5
expected annual costs + expected inventory investment €
294.189 €
288.879 €
305.609 €
293.033 €
285.075
average expected service level percent difference
0%
28%
28%
28%
28%
expected annual costs + expected inventory investment percent difference
0%
-2%
4%
0%
-3%
Table 6.1.1 Comparison of Common Operating Policy Scenarios—Expected Item Availability and Expected Costs
with the Safety factor (z) set to (z=2.33) a Cycle Service Level (CSL) at (CSL=99%) and a Probability of Stockout (1-CSL)=1%
approach. The additional complexity of such a method would need to be weighed against the potential improvements in expected item availability and the expected, additional, managerial costs.

Nonetheless, whether the service level is dictated by management as a set percentage for all medical items in a project, as was the case here, or the safety factor is calculated with reference to a critical ratio balance between expedited air transport and holding the medical item another order cycle, Simchi-Levi et al. (2008) note that everything else being equal, the higher the service level, the higher the inventory. Conversely, with relatively lower values for the safety factor, the potential for more costly expedited air transport is greater.

In either case, such results as those in Section 5.1 make transparent the risk assumed by the decision-maker.

6.2 Variability

The results reported for the expected item availability, the expected annual costs and the expected inventory investment (see Sections 5.1–5.6) were based upon the assumption of variable, or stochastic, demand. Demand was characterized not only by an average \((\mu_i)\) but by the variability \(\text{around that average (} \sigma_i)\). By considering both, it became possible to segment medical items based upon the key driver of demand variability as measured by the CV (see Section 4.2). The demand coefficient of variation (CV) considered both the average and the variability (see Equation 2.1.1). This distinction may be subtle, but is key. For as van Wassenhove (2012) notes, humanitarian logistics faces inventory problems under high uncertainty (see Section 2.3). As a measurement, the average demand does not inherently capture such uncertainty—it only subsumes the variability. Therefore, rule of thumb safety stock quantities based solely upon an average monthly consumption (AMC) fail to make obvious the
inherent variability. This was evidenced by the results of Scenario 1 in which safety stock was set as two months of the AMC (see Section 5.1). In Scenario 1, theoretically with such a rule of thumb not a single item from amongst the 143 non-zero quantity medical items (see Section 4.1) achieved an expected service level of greater than 95% (see Table 5.1.1). Practically, in 2017, the medical dispensary in this case study, experienced a stockout rate of 29% (Organization, 2017a).

In contrast, the results reported in Section 5 do not account for the variability in lead time. This simplifying assumption in the model deserves discussion, particularly in light of the above extolled virtues of measured variability. As noted by Simchi-Levi (2008), McGuire (2015), Willems (2016) and many others, lead time variability has been incorporated into various inventory management models. The choice to use a single-stage assessment based upon the Graves and Willems (2000) Guaranteed Service Time model brings with it the assumption of a known, constant lead time—no variability (see Section 2.3). In practice, when this guaranteed service assumption does not hold, lead time variability can impact expected item availability. In this case study, the maximum lead time coefficient of variation (CV-L) was 0.9 with the average (CV-L) of 0.2 and a standard deviation of 0.2 (see Table 4.1.1). Although theoretically possible to incorporate such lead time variability into the model the data necessary to do so was difficult to acquire. For instance, the determination of lead time variability per medical item required the export of data from two different ERP tools and its association and analysis via spreadsheets. As currently conceived, this process does not lend itself to repeatability at the field level. It was practically difficult. As such lead time variability was not incorporated.

6.3 Transport Modes

For the case under study, and with regards to inventory, the results indicated that procurement and transport costs were the majority of expected annual costs regardless of the
scenario (see Table 5.1.1). Thus transport modes merit discussion. A contrast between Scenarios 1 and 5 highlight how under certain circumstances, to include shorter review periods and reduced lead times, the total cost can be less even with air transport in lieu of ocean. In Scenario 5 air transport was used for medical items with a demand variability greater than or equal to 1.33 (CV≥1.33) provided that the expected replenishment size over the net replenishment time (τ) was less than or equal to one cubic meter (< 1m³). With the review period for these ‘high variability’ items reduced to three months (r=3) and air transport lead time set to one month (T=1) Scenario 5 had expected annual costs 22% less than those of Scenario 1. By comparison, Scenario 1 had a review period set to four months (r=4), ocean transport was set to four months (T=4) and a rule of thumb safety stock by which unavailable medical items required emergency expedition by air (see Table 3.1.1). Of course the initial expected inventory investment cost to adopt Scenario 5 was a factor of 1.3 greater than that of Scenario 1 (see Table 5.1.1). Even so, in terms of the overall expected cost (expected annual + expected inventory investment), Scenario 5 was 8% less expensive with a 22% increase in average expected service level than Scenario 1—this despite the fact that air transport was more expensive than ocean (see Appendix A).

What were the key differences between these two scenarios? Segmentation, safety stock based upon demand variability, a shorter review period and transport mode choices. Based upon segmentation Scenario 5 had two common operating policies, Scenario 1, one. Scenario 5 based the safety stock explicitly on variability of demand; it shortened the review period for highly variable (CV≥1.33) medical items to three months (r=3); and it transported such medical items by air (T=1), provided the expected replenishment size of the medical item over the net replenishment time (τ) was less than or equal to one cubic meter (≤ 1m³). In this case study, segmentation of medical items by demand variability and physical size, combined, with shorter
review periods and faster transportation modes theoretically provided a 22% increase in expected item availability with a total expected cost reduction of ~€25K. Though still a management decision, presumably this meets the criterion of appropriate cost.
7.0 Conclusion

In this case study of a medical dispensary in an ongoing humanitarian operation, the practitioner may wish to pay particular attention to alcohol-based hand rub in 500ml containers, ringer lactate in 1L flexible bags and medium, non-sterile latex examination gloves. Why? Beneficiaries and those who serve them rely on the availability of these items. Why else? The combined demand (FMC), demand variability (CV) and the physical size (m³) of these medical items may incur inappropriate costs to ship by air in the event of a stockout. For the Organization, safety stock determination based upon demand variability has been shown to theoretically increase expected item availability for all medical items, even at lower expected cost. By all accounts, it may be more complex to incorporate demand variability and physical size into inventory policies and segment accordingly. The desirability of the effort would likely depend on the level of risk, and associated cost, deemed acceptable. Nonetheless, informed decisions about groups of medical items may be possible when the information is available.

7.1 Key Insights

1. Expected item availability can improve when demand variability is formally considered.

For this case study, in an ongoing humanitarian operation, fewer stockouts were to be expected for medical items when certain item availability and cost drivers were formally considered, segments developed, and an appropriate common operating policy applied. Of particular interest were the key drivers of demand variability and the item size. Yet, even without segmentation greater item availability could theoretically be achieved by formally considering variability of demand. This would appear in-line with Kopczak’s observation (2003) that better demand information is important in any supply chain.
2. Segmentation benefits from visual assessment, iterative analysis and formal sensitivity analysis.

The boundaries of segments may not be apparent a priori. Visual assessment followed by iterative analysis of a spreadsheet model, such as the single-stage, Guaranteed Service Time model adapted from the Graves (2008), Neales (2015), and Willems (2016), provide a means to analyze the expected item availability, the expected annual costs and the expected inventory investment. Formal sensitivity analysis also provides a means to assess the potential boundaries within a key driver for segmentation.

3. For the practitioner, a clear, repeatable process may be preferable.

As parameters change, the drivers, segments and inventory policies may also change. Rather than a fragile but technically correct solution, a flexible, clear, repeatable process may be preferable. Spreadsheet models at field level for ongoing humanitarian operations may not be practical. The periodic calculation of demand variability from existing ERP data might however be in-and-of-itself valuable. The process alone would focus attention on those medical items more prone to item availability concerns.

4. Optimization is not necessary for improvement in outcomes.

Improvements in expected item availability and expected costs may be achieved without recourse to formal optimization. For instance, the inclusion of demand variability in safety stock calculations increased the average expected item availability from 77% to 95% over a rule of thumb approach, while reducing the annual expected costs.

5. Common operating policies can allow for decisions based upon informed levels of risk.

Common operating policies based upon segmentation allow decision-makers to compare various scenarios and assume informed levels of risk.
7.2 Challenges

As Kraljic notes (1983) “the greater the uncertainty of … [the] physical availability of those items, the more important supply management becomes.” Gralla, Goentzel, and Fine (2016) note that in “rapidly evolving emergency situations, operations managers have little time for problem formulation or solution.” Given these two perspectives, how can the importance of supply chain management, and in particular inventory management, be reconciled with the fact that field practitioners rarely have adequate time for the problem, even in ongoing humanitarian operations? Effective common operating policies. Yet, a number of challenges remain:

1. Models.

As Box (1986) notes, "Essentially, all models are wrong, but some are useful." A model is useful if it has the ability to explain, and reasonably predict, an outcome, such as expected item availability and expected cost. While humanitarian supply chains are complex, it may not be necessary to capture each and every driver of that complexity, nor every facet of the inherent variability, in order to make an informed decision about when and how much of a medical item to order. Yet, it is possible that models may be too simple if such a model does not adequately support decisions that lead to outcomes in which a primary objective of the Organization is met.

Therefore, a challenge remains to adequately demonstrate to decision-makers that simple policies are indeed preferable, only if such policies result in the desired outcome. Otherwise, some additional complexity, sufficiently modeled, is not meant to replace expert judgement, but support it. In fact, it may yield demonstrably better results than either alone.


For some practitioners in the case study, it was the belief that statistics does not have a role in inventory management. Presumably for most supply chain management academics, the
notion of inventory management without such math is difficult to imagine. Yet to bridge the gap between practitioners and academics, there needs to be a separation of the intuition and the math so as to support decisions, a notion championed by Caplice (2015). A mathematical formula has the power to efficiently capture the expected item availability and expected costs, given certain assumptions. Yet decision-makers benefit from visual representations, and the intuition which they represent, in order to make informed decisions about risk.

Therefore a challenge remains to adequately demonstrate to practitioners in ongoing humanitarian operations how statistical analysis may improve outcomes, while separating math from the intuition for decision support.

3. Cost

At times it appeared that any discussion of cost as regards humanitarian operations was taboo. And while a primary aim of the Organization appeared rightfully undisputed—to ensure the right medical item, in the right quantity, at the right time—secondary objectives matter: the subsequent clause of “whilst guaranteeing appropriate costs” (Organization, 2017b). Better outcomes appear intuitively possible when decision-makers are able to make informed decisions about expected item availability and the expected cost to “guarantee” it, though this may be an area for future research – see Section 7.3 item 4).

Therefore, a challenge remains to more appropriately incorporate notions of cost, particularly transport, holding, and stockout costs, into inventory management discussions and decisions within ongoing humanitarian operations for the Organization.
7.3 Extensions

1. Segments, mutual exclusivity and multiple transport modes.

A tenet of segmentation is that items belong to a single group, or as Protopappa-Sieke (2017) notes that there is mutual exclusivity. Conversely, Willems (2016) notes that there may be benefits when the same item uses two different means of transportation such as air and ocean. An extension of this adapted model would be research into segments which specifically and systematically allocate a portion of the replenishment to both modes of transportation.

2. Correlation of key driver characteristics to observable classifications.

The research conducted in this thesis focused on the key driver characteristics of each medical item. An area for future research would be the possible correlation of key driver characteristics with more generic characteristics such as the family or group of medical items as defined. This might provide a set of common operating policies based upon observable item characteristics.

3. Empiric model validation.

A comparison of the results of expected item availability and expected cost to the historic records of stockouts and the actual costs incurred in a project would provide a means to validate the methodology used in this thesis. This could be done through the application of this research methodology to another case study.
4. Inventory management support tools and operational outcomes.

An assumption of this research is that if presented with comparable inventory management options, decision-makers could make informed choices of risk and achieve better outcomes for the beneficiaries. Research, however, could examine if this is in fact the case.

5. Multiechelon inventory management.

This thesis examined whether common operating policies achieved through segmentation could improve item availability in ongoing humanitarian operations while maintaining appropriate costs. The scope of the research was a medical dispensary at field level. As such, the appropriate model was single-stage. Inventory management, however, goes beyond a single stage. Ultimately, it is the coordination between the different stages of a supply chain which has been shown to produce successful results (Graves & Willems, 2008). An area of research would thus be the application of multi-stage models to the humanitarian supply chain. The result might very well be the right item in the right place at the right time, all to the benefit of the beneficiaries.
Bibliography


### Summary Output

#### Regression Statistics

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*Appendix A. Transportation Cost Regression Results—Equation and Summary Output for Air and Ocean*
Ocean transportation cost ($Y$) equals:

\[
1491.78 + 0.07 \times \text{kg coefficient} + 93.78 \times \text{size coefficient}
\]

SUMMARY OUTPUT for independent as kg and volume

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Appendix A. Transportation Cost Regression Results—Equation and Summary Output for Air and Ocean
Appendix B. Sensitivity Analysis of the Expected Annual Cost and Expected Inventory Investment to a Range of Demand Variability (CV) segment boundaries (CV: 0-3.5) and physical size (m^3) of the demand over the net replenishment time (T) segment boundaries (m^2: 0-5). Simulation (n=2000) iterations.
Scenario:
base stock; review period of 4 months; 4 month total lead time; holding rate (a) of 0.15 ocean (i) transport

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Appendix C. Simulation Results by Scenario[1]
Scenario:
base stock; (r)evie period of 4counts; 4 month (T)otal lead time; holding rate (a) of 0.15 ocean (I transport

| Sample size | 2 |
| Statistic | Statistical assistance |
| Safety stock | Based on demand |
| Variability | 1 |

| Common operating policy | 2000 |
| Summation stats | Average | Standard deviation | Median | Upper 75% | Lower 25% | Max | Min | xbar±z*√n | xbar±z*√n |
|------------------------|-------|
| Average expected service level | 0.95 | 0.0000 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.9500 |

| Simulated average annual costs | €168.673 | €2.477 | €168.580 | €170.260 | €166.905 | €177.154 | €161.477 | €168.565 | €168.782 |
| Simulated average procurement (purchasing + transport) | €142.939 | €1.519 | €142.912 | €143.931 | €141.899 | €147.454 | €137.801 | €142.872 | €143.006 |
| Simulated average expected inventory investment (one-time) | €108.779 | €61 | €108.767 | €109.199 | €108.351 | €110.795 | €106.689 | €108.752 | €108.806 |
| Safety stock | €50.440 | €0 | €50.440 | €50.440 | €50.440 | €50.440 | €50.440 | €50.440 | €50.440 |
| Cycle stock | €50.440 | €0 | €50.440 | €50.440 | €50.440 | €50.440 | €50.440 | €50.440 | €50.440 |
| Simulated average pipeline stock | €38.893 | €42 | €38.885 | €39.172 | €38.608 | €40.237 | €37.499 | €38.875 | €38.911 |

Appendix C: Simulation Results by Scenario[2]
### Scenario:
- Base stock; (r)evie period of 4 months; 4 month (T)otal lead time; holding rate (a) of 0.15 ocean (I) transport
- Sample size: 3
- Statistical assist - if demand variability C(0.15, 1, 33
- (r)evie period=3 and transport by air with presumed lead time T=3;
- Safety stock based upon demand variability

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Simulated % of items with service level greater than or equal to 95%:
- 1.00

### Appendix C. Simulation Results by Scenario[3]
### Scenario:
- Base stock
- Review period of 4 months
- Total lead time
- Holding rate of 0.15
- Ocean transport
- Demand variability CV: 1.33
- Total size: 1
- Review period: 3
- Transport by air with a presumed lead time of 3
- Safety stock based upon demand variability

### Summary Stats

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### Statistics for Various Scenarios

- **Simulated Average Annual Costs:**
  - €168,581
  - €2,347
  - €168,537
  - €170,109
  - €167,014
  - €176,462
  - €160,559
  - €168,478
  - €168,684
- **Simulated Average Procurement (Purchasing + Transport):**
  - €142,906
  - €1,481
  - €142,886
  - €143,926
  - €141,898
  - €147,819
  - €137,518
  - €142,841
  - €142,971
- **Simulated Average Holding Cost:**
  - €16,314
  - €59
  - €16,314
  - €16,371
  - €16,353
  - €16,274
  - €16,500
  - €16,115
  - €16,311
  - €16,316
- **Simulated Average Stockout Costs:**
  - €9,362
  - €986
  - €9,338
  - €10,014
  - €8,673
  - €13,421
  - €6,358
  - €9,319
  - €9,405
- **Simulated Average Expected Inventory Investment (One-Time):**
  - €108,754
  - €595
  - €108,760
  - €107,912
  - €109,144
  - €108,361
  - €110,617
  - €106,767
  - €108,728
  - €108,780
- **Safety Stock:**
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- **Cycle Stock:**
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  - €50,440
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- **Simulated Average Pipeline Stock:**
  - €38,876
  - €396
  - €38,880
  - €38,315
  - €39,136
  - €38,614
  - €40,118
  - €37,552
  - €38,858
  - €38,893

### Appendix C. Simulation Results by Scenario[4]
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<td>€ 159.370</td>
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<td>€ 167.890</td>
</tr>
<tr>
<td>Simulated average procurement (purchasing + transport)</td>
<td>€ 142.956</td>
<td>€ 1.483</td>
<td>€ 142.927</td>
<td>€ 143.965</td>
<td>€ 141.960</td>
<td>€ 148.318</td>
<td>€ 137.923</td>
<td>€ 142.891</td>
<td>€ 143.021</td>
</tr>
<tr>
<td>Simulated average holding cost</td>
<td>€ 15.404</td>
<td>€ 58</td>
<td>€ 15.403</td>
<td>€ 15.442</td>
<td>€ 15.364</td>
<td>€ 15.596</td>
<td>€ 15.205</td>
<td>€ 15.401</td>
<td>€ 15.406</td>
</tr>
<tr>
<td>Simulated average expected inventory investment (one-time)</td>
<td>€ 102.690</td>
<td>€ 583</td>
<td>€ 102.684</td>
<td>€ 103.075</td>
<td>€ 102.294</td>
<td>€ 104.642</td>
<td>€ 100.731</td>
<td>€ 102.664</td>
<td>€ 102.716</td>
</tr>
<tr>
<td>Simulated average pipeline stock</td>
<td>€ 34.871</td>
<td>€ 385</td>
<td>€ 34.869</td>
<td>€ 35.125</td>
<td>€ 34.608</td>
<td>€ 36.150</td>
<td>€ 33.547</td>
<td>€ 34.854</td>
<td>€ 34.888</td>
</tr>
</tbody>
</table>

Simulated % of items with service level greater than or equal to 95%:

- 0.9990
- 0.9990
- 1.000
- 0.999
- 1.000
- 0.9990
- 0.9990
- 0.9990
- 0.9990
- 0.9990

**Appendix C. Simulation Results by Scenario[5]**
**Scenario 3 Segmentation**

Toward Effective Common Operating Policies for Medical Items in Ongoing Humanitarian Operations  
The Science and Art of Segmentation - A Case Study

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statistical assist -  
if demand variability CV\(\geq 1.33\) ; \(r\)eview period=3 and transport by air with presumed  
lead time T=3; safety stock based upon demand variability  
(n=91)

TETRACYCLINE hydrochloride, 1%, eye ointment, ster, 5g, tube  
ALCOHOL-BASED HAND RUB, solution, 100 ml, bot.  
ALCOHOL-BASED HAND RUB, solution, 500 ml, bot.  
ANTIHAEMORROID, ointment, 25 g, tube  
D.E.E.T., anti-mosquito repellent lotion  
HYDROCORTISONE (acetate or base), 1%, ointment, 15 g, tube  
SULFADIAZINE SILVER, 1%, cream, sterile, 50 g, tube  
PLASMA SUBSTITUTE, gelatin, 500 ml, flex. bag, PVC free  
RINGER lactate, 1 l, flex. bag, PVC free  
RINGER lactate, 500 ml, flex. bag, PVC free  
SODIUM chloride, 0.9%, 1 l, flex. bag, PVC free  
SODIUM chloride, 0.9%, 500 ml, flex. bag, PVC free  
AMPCILLIN, 1 g, powder, vial  
ARTESUNATE 60 mg, powder, vial +NaHCO3 5% 1 ml +NaCl 0.9% 5 ml  
CEFTRIAXONE sodium, eq. 1 g base, powder, vial  
DEXAMETHASONE phosphate, 4 mg/ml, 1 ml, amp.  
DIAZEPAM, 5 mg/ml, 2 ml, amp.  
DICLOFENAC sodium, 25 mg/ml, 3 ml, amp.  
EPINEPHRINE (adrenaline) tartrate, eq. 1 mg/ml base, 1 ml amp IV  
FUROSEMIDE, 10 mg/ml, 2 ml, amp.  
GENTAMICIN sulfate, eq. 40 mg/ml base, 2 ml, amp.  
GLUCOSE hypertonic, 50%, 50 ml, vial  
HYDROCORTISONE sodium succinate, eq. 100mg base, powder, vial  
LEVONORGESTREL implant 2 x 75 mg (Jadelle) + trocar  
LIDOCAINE hydrochloride, 1%, preservative-free, 10 ml, amp  
METRONIDAZOLE, 5 mg/ml, 100 ml, semi-rigid bot. PVC free  
ONDANSETRON hydrochloride, eq. 2 mg/ml base, 2 ml, amp.  
SALBUTAMOL sulfate, eq. 0.5 mg/ml base, 1 ml, amp.  
TRAMADOL hydrochloride, 50 mg/ml, 2 ml, amp.  
WATER for injection, 10 ml, plastic amp.  
ACETYLSALICYLIC acid (aspirin), 300 mg, tab.  
AMOXICILLIN 500mg/ CLAV.ac. 62.5mg/5ml, powder oral susp 60 ml  
AMOXICILLIN, 250 mg, tab.  
AL 20/120 mg, 12 disp. tab., blister, 15-24 kg

*Appendix D Segmentation Results for Medical Items*  
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AL 20/120 mg, 18 tab., blister, 25-34 kg
AZITHROMYCIN, 200mg/5ml, powder oral susp., bot.
CHLORPHENAMINE maleate, 4 mg, tab.
CODEINE phosphate, 30 mg, tab.
COTRIMOXAZOLE, 400 mg / 80 mg, tab.
DOXYCYCLINE salt, eq. 100 mg base, tab.
ERYTHROMYCIN stearate, eq. 250 mg base, tab.
ERYTHROMYCIN stearate, eq. 500 mg base, tab.
FOLIC acid, 5 mg, tab.
FUROSEMIDE, 40 mg, tab.
HYOSCINE BUTYLBROMIDE (scopolamine butylbromide), 10 mg, tab
IVERMECTIN (scabies + other indic.), 3 mg, tab.
METRONIDAZOLE, 250 mg, tab.
METOCLOPRAMIDE hydrochloride anhydrous, 10 mg, tab.
METHYLDOPA, 250 mg, tab.
MULTIVITAMINS, tab.
PHENOXYMETHYLPENICILLIN, 250 mg, tab.
PREDNISOLONE, 5 mg, tab.
PROMETHAZINE hydrochloride, eq. 25 mg base, tab.
PYRIDOXINE hydrochloride (vitamin B6), 50 mg, tab.
SALBUTAMOL sulfate, eq.0.1mg base/puff, 200 puffs, aerosol
SULFADOXINE, 500 mg / PYRIMETHAMINE, 25 mg, tab.
TINIDAZOLE, 500 mg, tab.
TRAMADOL hydrochloride, 50 mg, caps.
VACCINE HEPATITIS B, 1 adult dose, multidose vial
VACCINE TT (tetanus), 1 dose, multidose vial
TABLET COUNTER, triangular, metal, 17 cm
BANDAGE, ADHESIVE, elastic, 10 cm x 3 m
BANDAGE, CREPE (Velpeau), 10 cm x 4 m
DRESSING, HAEMOSTATIC (Quikclot ACS+)
COMPRESS, GAUZE, paraffin, 10 cm x 10 cm, sterile
TAPE, ADHESIVE, roll, 2 cm
CONTAINER, needles/syringes, 5 l, cardboard for incineration
IV CATHETER, injection port, s.u. 16 G (1.7 x 55 mm), grey
IV CATHETER, injection port, s.u. 18 G (1.2 x 45 mm), green
IV CATHETER, injection port, s.u. 20 G (1.0 x 32 mm), pink
IV CATHETER, injection port, s.u. 22 G (0.8 x 25 mm), blue
IV CATHETER, injection port, s.u. 24 G (0.7 x 19 mm) yellow
NEEDLE, s.u., Luer, 21 G (0.8 x 40 mm) green, IM
NEEDLE, s.u., Luer, 25 G (0.5 x 25 mm), orange, SC
NEEDLE, s.u., Luer, 26 G (0.45 x 13 mm), brown, ID
NEEDLE, SPINAL L.P., Luer, s.u., 20 G (0.9 x 90 mm)
NEEDLE, SPINAL L.P., Luer, s.u., 22 G (0.7 x 40 mm)
SCALP VEIN INFUSION SET, s.u., 21G (0.8 x 19 mm), green
SCALP VEIN INFUSION SET, s.u., 25G (0.5 x 19 mm), orange
SYRINGE, s.u., Luer, 2 ml
SYRINGE, s.u., Luer, 60 ml
BAG, plastic, for health card, 16 x 22 cm
GLOVE, EXAMINATION, latex, s.u. non sterile, medium
GLOVE, EXAMINATION, latex, s.u. non sterile, small
GLOVES, SURGICAL, latex, s.u., sterile, pair, 7.5
THERMOMETER, ELECTRONIC, accuracy 0.1 °C + case
MALARIA HRP-2 TEST (SD Bioline), whole blood, 1 test 05FK50
MALARIA HRP-2/pan pLDH TEST (SD Bioline), wb,1 test 05FK60
PREGNANCY RST/hCG TEST, urine, 1 strip
SUT. NON ABS. mono (1) needle 1/2 30mm taper
SUT. NON ABS. mono (2/0) needle 3/8 30mm rev. cutting

Scenario 3 Segmentation

Toward Effective Common Operating Policies for Medical Items in Ongoing Humanitarian Operations
The Science and Art of Segmentation - A Case Study

base stock/single-stage; (r)eview period of 4 months; 4 month (T)otal lead time; holding rate (α) of 0.15; ocean transport
(n=52)

BENZOIC ACID 6% / SALICYLIC ACID 3%, ointment, 40 g, tube
BENZYL BENZOATE, 25%, lotion, 1 l, bot.
CHLORHEXIDINE digluconate 5%, solution, 1 l, bot.
CLOTRIMAZOLE, 500 mg, vaginal tab. + applicator
POLYVIDONE IODINE, 10%, solution, 200 ml, dropper bot.
MICONAZOLE nitrate, 2%, cream, 30 g, tube
ZINC OXIDE, 10%, ointment, 100 g, tube
DEXTROSE (GLUCOSE), 5%, 500 ml, flex. bag. PVC free
ATROPINE sulfate, 1 mg/ml, 1 ml, amp.
HYOSCINE BUTYLBROMIDE (scopolamine butylbrom), 20 mg/1ml, amp
ACICLOVIR, 800 mg, tab.
ALBENDAZOLE, 400 mg, tab.
ALUMINIUM hydroxide 400mg / MAGNESIUM hydroxide 400mg, tab.
AMITRIPTYLINE hydrochloride, 25 mg, tab.
AMOXICILLIN 500mg / CLAVULANIC acid, 62.5 mg, tab.
AMOXICILLIN, 125mg/5ml, powder oral susp., 100 ml, bot.
AMOXICILLIN, 500 mg, tab.
AL 20/120 mg, 6 disp. tab., blister, 5-14 kg

Appendix D Segmentation Results for Medical Items
<table>
<thead>
<tr>
<th>Item Description</th>
<th>Quantity</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL 20/120 mg, 24 tab., blister, &gt;35 kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AZITHROMYCIN, 250 mg, tab.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEFIXIME, 200 mg, tab.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIPROFLOXACIN hydrochloride, eq. 500 mg base, tab.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLOXACILLIN sodium, eq. 250 mg base, caps.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COTRIMOXAZOLE, 200 mg/40 mg/5 ml, oral susp, 100 ml, bot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ERYTHROMYCIN ethylsucc. 125 mg/5 ml, powder oral susp, 100 ml, bot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FERROUS salt eq. 60 mg iron / FOLIC acid 0.4 mg, tab</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLUCONAZOLE, 50 mg/5 ml, powder oral susp., bot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLUCONAZOLE, 200 mg, caps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GRISEOFULVIN, 500 mg, tab.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBUPROFEN, 100 mg/5 ml, oral susp., 150 ml, bot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBUPROFEN, 200 mg, tab.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBUPROFEN, 400 mg, tab.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>METRONIDAZOLE benzoate, eq. 200 mg/5 ml, oral susp., 100 ml</td>
<td></td>
<td></td>
</tr>
<tr>
<td>METRONIDAZOLE, 500 mg, tab.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NYSTATIN, 100K IU/ml, oral susp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OMEPRAZOLE, 20 mg, gastro-resistant caps.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ORAL REHYDRATION SALTS (ORS) low osmol., sachet 20.5 g/1l</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PARACETAMOL (acetaminophen), 120 mg/5 ml, oral susp., 100 ml, bot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PARACETAMOL (acetaminophen), 100 mg, tab.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PARACETAMOL (acetaminophen), 500 mg, tab.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BAG, plastic, for drugs, 6 x 8 cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BANDAGE, EXTENSIBLE, non adhesive, 6 to 7 cm x 4 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMPRESS, NON WOVEN, 4 plies, 7.5 cm, non sterile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMPRESS, GAUZE, 10 cm, 12 plies, 17 threads, sterile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COTTON WOOL, hydrophilic, roll, 500 g</td>
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<td></td>
</tr>
<tr>
<td>TAPE, ADHESIVE, roll, perforated, 10 cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEEDLE, s.u., Luer, 19 G (1.1 x 40 mm) cream, IV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEEDLE, s.u., Luer, 23 G (0.6 x 30 mm) blue, SC, IM child</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SET, INFUSION 'Y', Luer lock, air inlet, sterile, s.u.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SYRINGE, s.u., Luer, 5 ml</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SYRINGE, s.u., Luer, 10 ml</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CONDOM, lubricated + RESERVOIR, s.u.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Scenario 4 Segmentation
Toward Effective Common Operating Policies for Medical Items in Ongoing Humanitarian Operations
The Science and Art of Segmentation - A Case Study

statistical assist -
if demand variability CV≥1.33 and if total sizes≤1m³; review period=3 and transport by air
with presumed lead time T=3 and safety stock based upon demand variability
(n=88)

TETRACYCLINE hydrochloride, 1%, eye ointment, ster, 5g, tube
ALCOHOL-BASED HAND RUB, solution, 100 ml, bot.
ANTIHAEMORROID, ointment, 25 g, tube
D.E.T., anti-mosquito repellent lotion
HYDROCORTISONE (acetate or base), 1%, ointment, 15 g, tube
SULFADIAZINE SILVER, 1%, cream, sterile, 50 g, tube
PLASMA SUBSTITUTE, gelatin, 500 ml, flex. bag, PVC free
RINGER lactate, 500 ml, flex. bag, PVC free
SODIUM chloride, 0.9%, 1 l, flex. bag, PVC free
SODIUM chloride, 0.9%, 500 ml, flex. bag, PVC free
AMPLICILLIN, 1 g, powder, vial
ARTESTUNATE 60 mg, powder, vial + NaHCO3 5% 1 ml + NaCl 0.9% 5 ml
CEFTRIAXONE sodium, eq. 1 g base, powder, vial
Dexamethasone phosphate, 4 mg/ml, 1 ml, amp.
DIAZEPAM, 5 mg/ml, 2 ml, amp.
DICLOFENAC sodium, 25 mg/ml, 3 ml, amp.
EPINEPHRINE (adrenaline) tartrate, eq. 1 mg/ml base, 1 ml amp IV
FUROSEMIDE, 10 mg/ml, 2 ml, amp.
GENTAMICIN sulfate, eq. 40 mg/ml base, 2 ml, amp.
GLUCOSE hypertonic, 50%, 50 ml, vial
HYDROCORTISONE sodium succinate, eq. 100 mg base, powder, vial
LEVONORGESTREL implant 2 x 75 mg (Jadelle) + trocar
LIDOCAINE hydrochloride, 1%, preservative-free, 10 ml, amp.
METRONIDAZOLE, 5 mg/ml, 100 ml, semi-rigid bot. PVC free
ONDANSETRON hydrochloride, eq. 2 mg/ml base, 2 ml, amp.
SALBUTAMOL sulfate, eq. 0.5 mg/ml base, 1 ml, amp.
TRAMADOL hydrochloride, 50 mg/ml, 2 ml, amp.
WATER for injection, 10 ml, plastic amp.
ACETYLSALICYLIC acid (aspirin), 300 mg, tab.
AMOXICILLIN 500 mg/ CLAV.ac. 62.5 mg/5 ml, powder oral susp 60 ml
AMOXICILLIN, 250 mg, tab.
AL 20/120 mg, 12 disp. tab., blister, 15-24 kg
AL 20/120 mg, 18 tab., blister, 25-34 kg
AZITHROMYCIN, 200 mg/5 ml, powder oral susp., bot.

Appendix D Segmentation Results for Medical Items
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CHLORPHENAMINE maleate, 4 mg, tab.
CODEINE phosphate, 30 mg, tab.
COTRIMOXAZOLE, 400 mg / 80 mg, tab.
DOXYCYCLINE salt, eq. 100 mg base, tab.
ERYTHROMYCIN stearate, eq. 250 mg base, tab.
ERYTHROMYCIN stearate, eq. 500 mg base, tab.
FOLIC acid, 5 mg, tab.
FUROSEMIDE, 40 mg, tab.
HYOSCINE BUTYLBROMIDE (scopolamine butylbromide), 10 mg, tab
IVERMECTIN (scabies + other indic.), 3 mg, tab.
METRONIDAZOLE, 250 mg, tab.
METOCLOPRAMIDE hydrochloride anhydrous, 10 mg, tab.
METHYLDOPA, 250 mg, tab.
MULTIVITAMINS, tab.
PHENOXYMETHYLENICILLIN, 250 mg, tab.
PREDNISOLONE, 5 mg, tab.
PROMETHAZINE hydrochloride, eq. 25 mg base, tab.
PYRIDOXINE hydrochloride (vitamin B6), 50 mg, tab.
SALBUTAMOL sulfate, eq.0.1mg base/puff, 200 puffs, aerosol
SULFADOXINE, 500 mg / PYRIMETHAMINE, 25 mg, tab.
TINIDAZOLE, 500 mg, tab.
TRAMADOL hydrochloride, 50 mg, caps.
VACCINE HEPATITIS B, 1 adult dose, multidose vial
VACCINE TT (tetanus), 1 dose, multidose vial
TABLET COUNTER, triangular, metal, 17 cm
BANDAGE, ADHESIVE, elastic, 10 cm x 3 m
BANDAGE, CREPE (Velpeau), 10 cm x 4 m
DRESSING, HAEMOSTATIC (Quikclot ACS+)
COMPRESS, GAUZE, paraffin, 10 cm x 10 cm, sterile
TAPE, ADHESIVE, roll, 2 cm
CONTAINER, needles/syringes, 5 l, cardboard for incineration
IV CATHETER, injection port, s.u. 16 G (1.7 x 55 mm), grey
IV CATHETER, injection port, s.u. 18 G (1.2 x 45 mm), green
IV CATHETER, injection port, s.u. 20 G (1.0 x 32 mm), pink
IV CATHETER, injection port, s.u. 22 G (0.8 x 25 mm), blue
IV CATHETER, injection port, s.u. 24 G (0.7 x 19 mm) yellow
NEEDLE, s.u., Luer, 21 G (0.8 x 40 mm) green, IM
NEEDLE, s.u., Luer, 25 G (0.5 x 25 mm), orange, SC
NEEDLE, s.u., Luer, 26 G (0.45 x 13 mm), brown, ID
NEEDLE, SPINAL L.P., Luer, s.u., 20 G (0.9 x 90 mm)
NEEDLE, SPINAL L.P., Luer, s.u., 22 G (0.7 x 40 mm)
SCALP VEIN INFUSION SET, s.u., 21G (0.8 x 19 mm), green
SCALP VEIN INFUSION SET, s.u., 25G (0.5 x 19 mm), orange
Syringe, s.u., Luer, 2 ml
Syringe, s.u., Luer, 60 ml
Bag, plastic, for health card, 16 x 22 cm
Glove, examination, latex, s.u. non sterile, small
Gloves, surgical, latex, s.u., sterile, pair, 7.5
Thermometer, electronic, accuracy 0.1? C + case
Malaria HRP-2 test (SD Bioline), whole blood, 1 test 05FK50
Malaria HRP-2/pan pLDH test (SD Bioline), wb, 1 test 05FK60
Pregnancy RST/hCG test, urine, 1 strip
Sut. non abs. mono (1) needle 1/2 30mm taper
Sut. non abs. mono (2/0) needle 3/8 30mm rev. cutting

Scenario 4 Segmentation
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Base stock/single-stage; (r)eview period of 4 months; 4 month (T)otal lead time; holding rate (a) of 0.15; ocean transport
(n=55)

Alcohol-based hand rub, solution, 500 ml, bot.*
Benzoic acid 6% / Salicylic acid 3%, ointment, 40 g, tube
Benzy1 benzoate, 25%, lotion, 1 l, bot.
Chlorhexidine digluconate 5%, solution, 1 l, bot.
Clotrimazole, 500 mg, vaginal tab. + applicator
Polyvidone Iodine, 10%, solution, 200 ml, dropper bot.
Miconazole nitrate, 2%, cream, 30 g, tube
Zinc oxide, 10%, ointment, 100 g, tube
Dextrose (Glucose), 5%, 500 ml, flex. bag, PVC free
Ringer lactate, 1 l, flex. bag, PVC free*
Atropine sulfate, 1 mg/ml, 1 ml, amp.
Hyoscine butylbromide (scopolamine butylbrom), 20 mg/1ml, amp
Aciclovir, 800 mg, tab.
Albendazole, 400 mg, tab.
Aluminum hydroxide 400mg / Magnesium hydroxide 400mg, tab.
Amitriptyline hydrochloride, 25 mg, tab.
Amoxicillin 500mg / Clavulanic acid, 62.5 mg, tab.
Amoxicillin, 125mg/5ml, powder oral susp., 100 ml, bot.
Amoxicillin, 500 mg, tab.
Al 20/120 mg, 6 disp. tab., blister, 5-14 kg
Al 20/120 mg, 24 tab., blister, >35 kg

Appendix D Segmentation Results for Medical Items
88
AZITHROMYCIN, 250 mg, tab.
CEFIXIME, 200 mg, tab.
CIPROFLOXACIN hydrochloride, eq. 500 mg base, tab.
CLOXACILLIN sodium, eq. 250 mg base, caps.
COTRIMOXAZOLE, 200mg/40mg/5ml, oral susp,100 ml, bot.
ERYTHROMYCIN ethylsucc. 125mg/5ml, powder oral susp. 100ml, bot
FERROUS salt eq. 60 mg iron / FOLIC acid 0.4 mg, tab
FLUCONAZOLE, 50mg/5ml, powder oral susp., bot.
FLUCONAZOLE, 200 mg, caps.
GRISEOFULVIN, 500 mg, tab.
IBUPROFEN, 100mg/5ml, oral susp., 150 ml, bot.
IBUPROFEN, 200 mg, tab.
IBUPROFEN, 400 mg, tab.
METRONIDAZOLE benzoate, eq.200mg/5ml base, oral susp., 100ml
METRONIDAZOLE, 500 mg, tab.
NYSTATIN, 100,000 IU/ml, oral susp.
OMEPRAZOLE, 20 mg, gastro-resistant caps.
ORAL REHYDRATION SALTS (ORS) low osmol., sachet 20.5 g/1l
PARACETAMOL (acetaminophen), 120mg/5ml, oral susp., 100ml bot.
PARACETAMOL (acetaminophen), 100 mg, tab.
PARACETAMOL (acetaminophen), 500 mg, tab.
BAG, plastic, for drugs, 6 x 8 cm
BANDAGE, EXTENSIBLE, non adhesive, 6 to 7 cm x 4 m
COMPRESS, NON WOVEN, 4 plies, 7.5 cm, non sterile
COMPRESS, GAUZE, 10 cm, 12 plies, 17 threads, sterile
COTTON WOOL, hydrophilic, roll, 500 g
TAPE, ADHESIVE, roll, perforated, 10 cm
NEEDLE, s.u., Luer, 19 G (1.1 x 40 mm) cream, IV
NEEDLE, s.u., Luer, 23 G (0.6 x 30mm) blue, SC, IM child
SET, INFUSION 'Y', Luer lock, air inlet, sterile, s.u.
SYRINGE, s.u., Luer, 5 ml
SYRINGE, s.u., Luer, 10 ml
CONDOM, lubricated + RESERVOIR, s.u.

GLOVE, EXAMINATION, latex, s.u. non sterile, medium *
* [consider partial by air as CV≥1.33 (n=3)]
Scenario 5 Segmentation
Toward Effective Common Operating Policies for Medical Items in Ongoing Humanitarian Operations
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Statistical assist:
If demand variability CV ≥ 1.33 and if total size ≤ 1 m³, review period = 3 and transport by air
with presumed lead time T = 1 and safety stock based upon demand variability
(n = 88)

TETRACYCLINE hydrochloride, 1%, eye ointment, ster, 5 g, tube
ALCOHOL-BASED HAND RUB, solution, 100 ml, bot.
ANTIHAEMORROID, ointment, 25 g, tube
D.E.T., anti-mosquito repellent lotion
HYDROCORTISONE (acetate or base), 1%, ointment, 15 g, tube
SULFADIAZINE SILVER, 1%, cream, sterile, 50 g, tube
PLASMA SUBSTITUTE, gelatin, 500 ml, flex. bag, PVC free
RINGER lactate, 500 ml, flex. bag, PVC free
SODIUM chloride, 0.9%, 1 l, flex. bag, PVC free
SODIUM chloride, 0.9%, 500 ml, flex. bag, PVC free
AMPICILLIN, 1 g, powder, vial
ARTESUNATE 60 mg, powder, vial + NaHCO3 5% 1 ml + NaCl 0.9% 5 ml
CEFTRIAXONE sodium, eq. 1 g base, powder, vial
DEXAMETHASONE phosphate, 4 mg/ml, 1 ml, amp.
DIAZEPAM, 5 mg/ml, 2 ml, amp.
DICLOFENAC sodium, 25 mg/ml, 3 ml, amp.
EPINEPHRINE (adrenaline) tartrate, eq. 1 mg/ml base, 1 ml amp IV
FUROSEMIDE, 10 mg/ml, 2 ml, amp.
GENTAMICIN sulfate, eq. 40 mg/ml base, 2 ml, amp.
GLUCOSE hypertonic, 50%, 50 ml, vial
HYDROCORTISONE sodium succinate, eq. 100 mg base, powder, vial
LEVONORGESTREL implant 2 x 75 mg (Jadelle) + trocar
LIDOCAINE hydrochloride, 1%, preservative-free, 10 ml, amp
METRONIDAZOLE, 5 mg/ml, 100 ml, semi-rigid bot. PVC free
ONDANSETRON hydrochloride, eq. 2 mg/ml base, 2 ml, amp.
SALBUTAMOL sulfate, eq. 0.5 mg/ml base, 1 ml, amp.
TRAMADOL hydrochloride, 50 mg/ml, 2 ml, amp.
WATER for injection, 10 ml, plastic amp.
ACETYLSALICYLIC acid (aspirin), 300 mg, tab.
AMOXICILLIN 500 mg/ CLAV. ac. 62.5 mg/ 5 ml, powder oral susp 60 ml
AMOXICILLIN, 250 mg, tab.
AL 20/120 mg, 12 disp. tab., blister, 15-24 kg

Appendix D Segmentation Results for Medical Items

90
AL 20/120 mg, 18 tab., blister, 25-34 kg
AZITHROMYCIN, 200mg/5ml, powder oral susp., bot.
CHLORPHENAMINE maleate, 4 mg, tab.
CODEINE phosphate, 30 mg, tab.
COTRIMOXAZOLE, 400 mg / 80 mg, tab.
DOXYCYCLINE salt, eq. 100 mg base, tab.
ERYTHROMYCIN stearate, eq. 250 mg base, tab.
ERYTHROMYCIN stearate, eq. 500 mg base, tab.
FOLIC acid, 5 mg, tab.
FUROSEMIDE, 40 mg, tab.
HYOSCINE BUTYLBROMIDE (scopolamine butylbromide), 10 mg, tab
IVERMECTIN (scabies + other indic.), 3 mg, tab.
METRONIDAZOLE, 250 mg, tab.
METOCLOPRAMIDE hydrochloride anhydrous, 10 mg, tab.
METHYLDOPA, 250 mg, tab.
MULTIVITAMINS, tab.
PHENOXYMETHYLPENICILLIN, 250 mg, tab.
PREDNISOLONE, 5 mg, tab.
PROMETHAZINE hydrochloride, eq. 25 mg base, tab.
PYRIDOXINE hydrochloride (vitamin B6), 50 mg, tab.
SALBUTAMOL sulfate, eq.0.1mg base/puff, 200 puffs, aerosol
SULFADOXINE, 500 mg / PYRIMETHAMINE, 25 mg, tab.
TINIDAZOLE, 500 mg, tab.
TRAMADOL hydrochloride, 50 mg, caps.
VACCINE HEPATITIS B, 1 adult dose, multidose vial
VACCINE TT (tetanus), 1 dose, multidose vial
TABLET COUNTER, triangular, metal, 17 cm
BANDAGE, ADHESIVE, elastic, 10 cm x 3 m
BANDAGE, CREPE (Velpeau), 10 cm x 4 m
DRESSING, HAEMOSTATIC (Quikclot ACS+), unit
COMPRESS, GAUZE, paraffin, 10 cm x 10 cm, sterile
TAPE, ADHESIVE, roll, 2 cm
CONTAINER, needles/syringes, 5 l, cardboard for incineration
IV CATHETER, injection port, s.u. 16 G (1.7 x 55 mm), grey
IV CATHETER, injection port, s.u. 18 G (1.2 x 45 mm), green
IV CATHETER, injection port, s.u. 20 G (1.0 x 32 mm), pink
IV CATHETER, injection port, s.u. 22 G (0.8 x 25 mm), blue
IV CATHETER, injection port, s.u. 24 G (0.7 x 19 mm) yellow
NEEDLE, s.u., Luer, 21 G (0.8 x 40 mm) green, IM
NEEDLE, s.u., Luer, 25 G (0.5 x 25 mm), orange, SC
NEEDLE, s.u., Luer, 26 G (0.45 x 13 mm), brown, ID
NEEDLE, SPINAL L.P., Luer, s.u., 20 G (0.9 x 90 mm)
NEEDLE, SPINAL L.P., Luer, s.u., 22 G (0.7 x 40 mm)
SCALP VEIN INFUSION SET, s.u., 21G (0.8 x 19 mm), green
SCALP VEIN INFUSION SET, s.u., 25G (0.5 x 19 mm), orange
SYRINGE, s.u., Luer, 2 ml
SYRINGE, s.u., Luer, 60 ml
BAG, plastic, for health card, 16 x 22 cm
GLOVE, EXAMINATION, latex, s.u. non sterile, small
GLOVES, SURGICAL, latex, s.u., sterile, pair, 7.5
THERMOMETER, ELECTRONIC, accuracy 0.1? C + case
MALARIA HRP-2 TEST (SD Bioline), whole blood, 1 test 05FK50
MALARIA HRP-2/pan pLDH TEST (SD Bioline), wb, 1 test 05FK60
PREGNANCY RST/hCG TEST, urine, 1 strip
SUT. NON ABS. mono (1) needle 1/2 30mm taper
SUT. NON ABS. mono (2/0) needle 3/8 30mm rev. cutting
**Scenario 5 Segmentation**

*Toward Effective Common Operating Policies for Medical Items in Ongoing Humanitarian Operations*

*The Science and Art of Segmentation - A Case Study*

- **base stock/single-stage; (r) review period of 4 months; 4 month (T)otal lead time; holding rate (a) of 0.15; ocean transport**

(n=55)

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Formulation</th>
<th>Quantity</th>
<th>Unit</th>
<th>Additional Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALCOHOL-BASED HAND RUB, solution</td>
<td>500 ml, bot.*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BENZOIC ACID 6% / SALICYLIC ACID 3%</td>
<td>ointment, 40 g, tube</td>
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<tr>
<td>BENZYL BENZOATE</td>
<td>25%, lotion, 1 l, bot.</td>
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<tr>
<td>CHLORHEXIDINE digluconate 5%</td>
<td>solution, 1 l, bot.</td>
<td></td>
<td></td>
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<tr>
<td>CLOTRIMAZOLE</td>
<td>500 mg, vaginal tab. + applicator</td>
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<tr>
<td>POLYVIDONE IODINE</td>
<td>10%, solution, 200 ml, dropper bot.</td>
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<tr>
<td>MICONAZOLE nitrate, 2%</td>
<td>cream, 30 g, tube</td>
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<td></td>
<td></td>
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<tr>
<td>ZINC OXIDE</td>
<td>10%, ointment, 100 g, tube</td>
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<tr>
<td>DEXTROSE (GLUCOSE)</td>
<td>5%, 500 ml, flex. bag, PVC free</td>
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<tr>
<td>RINGER lactate</td>
<td>1 l, flex. bag, PVC free*</td>
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<tr>
<td>ATROPINE sulfate</td>
<td>1 mg/ml, 1 ml, amp.</td>
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<tr>
<td>HYOSCINE BUTYLBROMIDE (scopolamine butylbrom)</td>
<td>20 mg/1ml, amp</td>
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<tr>
<td>ACICLOVIR</td>
<td>800 mg, tab.</td>
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<tr>
<td>ALBENDAZOLE</td>
<td>400 mg, tab.</td>
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<tr>
<td>ALUMINIUM hydroxide 400mg / MAGNESIUM</td>
<td>hydroxide 400mg, tab.</td>
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<tr>
<td>AMITRIPTYLINE hydrochloride</td>
<td>25 mg, tab.</td>
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<tr>
<td>AMOXICILLIN 500mg / CLAVULANIC acid</td>
<td>62.5 mg, tab.</td>
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<tr>
<td>AMOXICILLIN 125mg/5ml, powder oral susp.</td>
<td>100 ml, bot.</td>
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<tr>
<td>AMOXICILLIN 500 mg, tab.</td>
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<td></td>
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<tr>
<td>AL 20/120 mg, 6 disp. tab., blister</td>
<td>5-14 kg</td>
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<td></td>
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<tr>
<td>AL 20/120 mg, 24 tab., blister</td>
<td>&gt;35 kg</td>
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<tr>
<td>AZITHROMYCIN</td>
<td>250 mg, tab.</td>
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<tr>
<td>CEFIXIME</td>
<td>200 mg, tab.</td>
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<tr>
<td>CIPROFLOXACIN hydrochloride</td>
<td>eq. 500 mg base, tab.</td>
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<tr>
<td>CLOXACILLIN sodium</td>
<td>eq. 250 mg base, caps.</td>
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<tr>
<td>COTRIMOXAZOLE</td>
<td>200mg/40mg/5ml, oral susp, 100 ml, bot.</td>
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<tr>
<td>ERYTHROMYCIN ethylsucc.</td>
<td>125mg/5ml, powder oral susp, 100ml, bot</td>
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<tr>
<td>FERROUS salt eq. 60 mg iron / FOLIC acid 0.4 mg</td>
<td>tab</td>
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<tr>
<td>FLUCONAZOLE</td>
<td>50mg/5ml, powder oral susp., bot.</td>
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<tr>
<td>FLUCONAZOLE</td>
<td>200 mg, caps. [Use for Kit production only!!! Please order: DORAFLUC2T]</td>
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<tr>
<td>GRISEOFULVIN</td>
<td>500 mg, tab.</td>
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<tr>
<td>IBUPROFEN</td>
<td>100mg/5ml, oral susp., 150 ml, bot.</td>
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<tr>
<td>IBUPROFEN</td>
<td>200 mg, tab.</td>
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<tr>
<td>IBUPROFEN</td>
<td>400 mg, tab.</td>
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</tbody>
</table>

*Appendix D Segmentation Results for Medical Items*
METRONIDAZOLE benzoate, eq.200mg/5ml base, oral susp., 100ml
METRONIDAZOLE, 500 mg, tab.
NYSTATIN, 100K IU/ml, oral susp.
Omeprazole, 20 mg, gastro-resistant caps.
ORAL REHYDRATION SALTS (ORS) low osmol., sachet 20.5 g/1l
PARACETAMOL (acetaminophen), 120mg/5ml, oral susp., 100ml bot.
PARACETAMOL (acetaminophen), 100 mg, tab.
PARACETAMOL (acetaminophen), 500 mg, tab.
BAG, plastic, for drugs, 6 x 8 cm
BANDAGE, EXTENSIBLE, non adhesive, 6 to 7 cm x 4 m
COMPRESS, NON WOVEN, 4 plies, 7.5 cm, non sterile
COMPRESS, GAUZE, 10 cm, 12 plies, 17 threads, sterile
COTTON WOOL, hydrophilic, roll, 500 g
TAPE, ADHESIVE, roll, perforated, 10 cm
NEEDLE, s.u., Luer, 19 G (1.1 x 40 mm) cream, IV
NEEDLE, s.u., Luer, 23 G (0.6 x 30mm) blue, SC, IM child
SET, INFUSION 'Y', Luer lock, air inlet, sterile, s.u.
SYRINGE, s.u., Luer, 5 ml
SYRINGE, s.u., Luer, 10 ml
CONDOM, lubricated + RESERVOIR, s.u.
GLOVE, EXAMINATION, latex, s.u. non sterile, medium*
* [consider partial by air as CV≥1.33 (n=3)]