Evaluation of Inventory Management Policies in Hospitals' Medication Supply Chain

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Introduction

As the supply chain costs constitute a large portion of hospitals' operating expenses [1], and $26.8 billion was spent by the US hospitals on drugs alone in 2006 [2], improving medication inventory management provides a great opportunity to decrease the cost of healthcare. The specific aim of this study is to investigate different management approaches for the system consisting of one main pharmacy and multiple dispensing machines located in each department (Figure 1), where medications have different unit cost and three other important characteristics: availability from suppliers, criticality and expiration date.

Methods

The solution approach consisted of several interrelated steps presented in Figure 2. Computer simulation (Figure 3) was used to evaluate the performance of several inventory policies based on the total cost and patient safety under various arrangements of the system. The simulation model was built based on 60 hours of direct observations and conversations with pharmacy staff. Historical data from the information system of a community hospital with 86 beds was analyzed using Arena Input Analyzer to determine distributions of demand (time between orders and dose size) for different medications and the associated distributions of unit cost. Additionally, distributions of the drug availability from supplier, drug criticality and drug expiration window were created for two levels of these characteristics (low-high or long-short) based on experiences of the purchasing technician and pharmacists. These information were used to generate random instances of problems defined by the number of drugs and the criticality, availability and expiration window levels.

Five periodic review inventory management policies were developed. The policies consider various factors and try to balance different cost components. Table 1 presents a brief explanation of these policies. Experimental design was used to assess the impact of the policies on the system performance in different problems (Table 2 shows all factors used).

Results

Based on simulation outputs (Table 3), system performance was evaluated in terms of cost and safety. Figure 4 shows that significant financial benefits can be obtained when considering more factors affecting medication supply chain. Policies 4 and 5 display

improvement of 19.5% and 23.5%, respectively, over policy 1 which most accurately corresponds to most hospitals' operations. Comparison to real hospitals could be even more impressive as it was noticed that even simple policies are often missing or are not followed consistently in many organizations.

Additionally, Policy 4 provides safer environment by decreasing the number of critical stockouts at the dispensing machine (Figure 5) and critical hospital-wide stockouts (Figure 6). This last measure is especially important as critical global shortage can result in serious consequences.

Discussion

The study indicates that considering drug's criticality, availability and expiration window, in addition to the cost and usage (most widely used in hospitals) can result in much better system performance in terms of both the cost and patient safety. It is possible to generalize the findings into a decision algorithm that could be used to set appropriate inventory levels for medications and supplies, and choose the best reordering policy to manage these levels across the hospital.

[1] Kamani, P., 15 June 2004, "Hospital Supply Chain Savings," Ascet, San Francisco: Montgomery Research Inc., 10 October 2008, <www.unspsc.org/AdminFolder/Documents/Montgomery_Kamani_FINAL.pdf>.

[2] Hoffman, J.M., Shah, N.D., Vermeulen, L.C., Doloresco, F., Grim, P., Hunkler R.J., Hontz K.M., Schumock G.T., 2008, "Projecting Future Drug Expenditures – 2008," *American Journal of Health-System Pharmacy*, vol. 65; pp. 234-253.

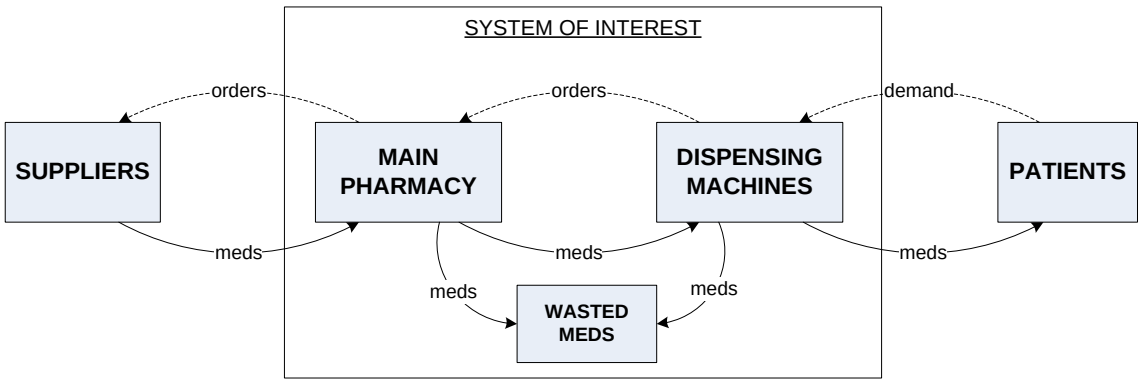


Figure 1 – Overview of the general medication flow system

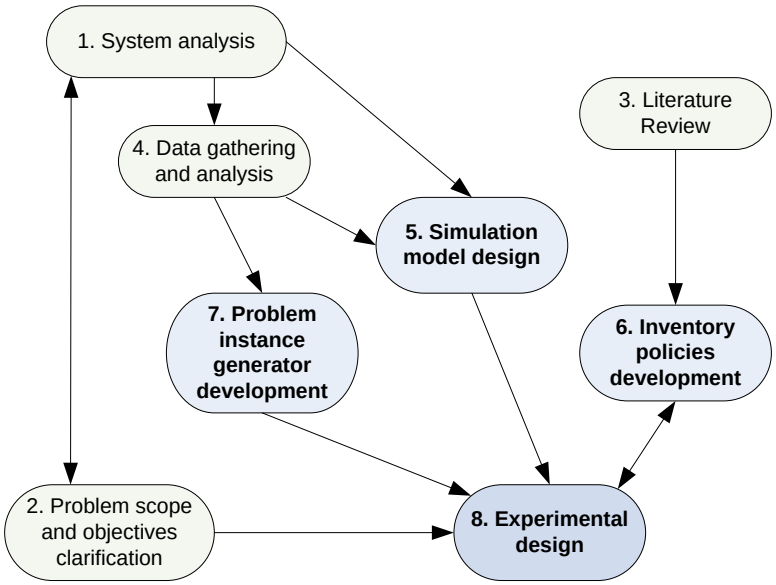


Figure 2 – Major steps of the solution approach

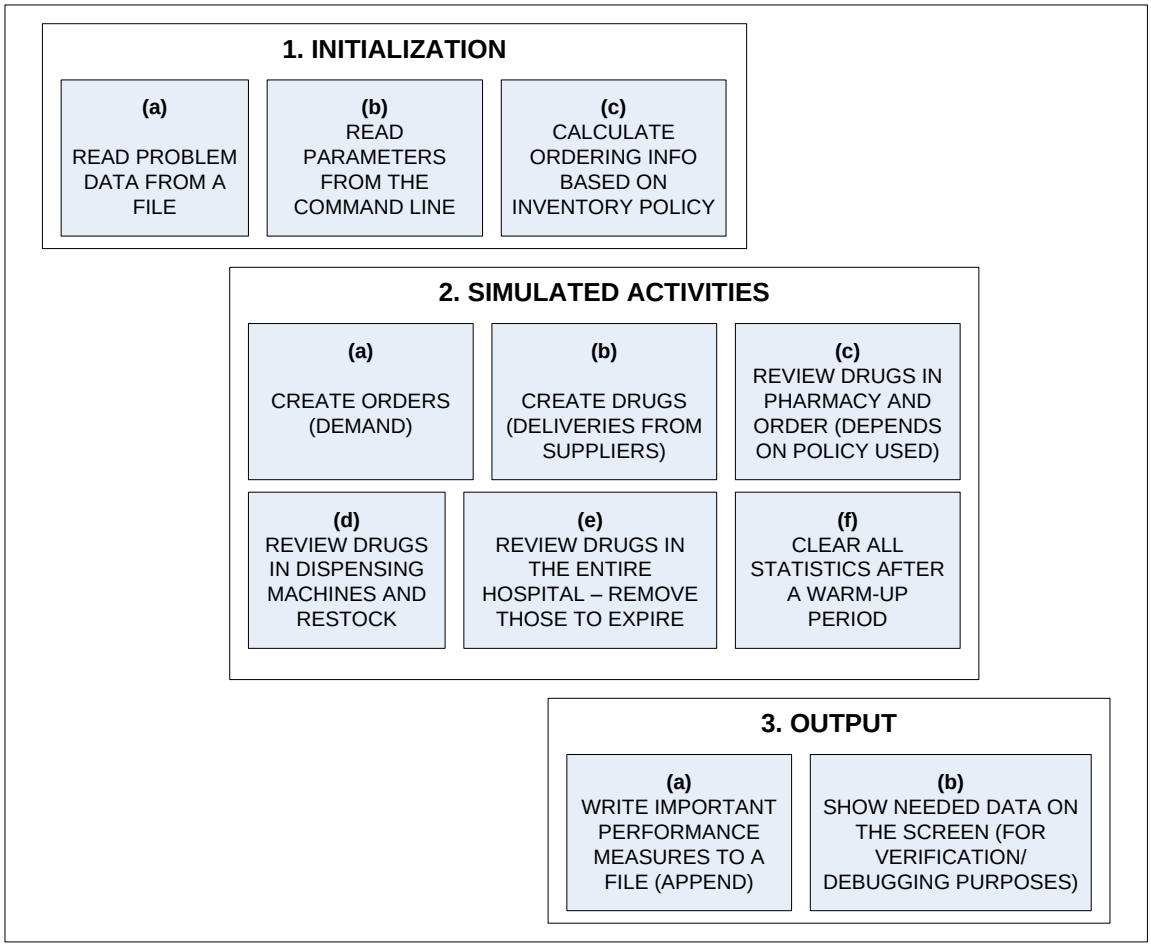


Figure 3 – Computer simulation structure

Table 1 – Explanation of inventory management policies used in the study

Policy	Explanation
1	▪ Uses (R, S) model where inventory is reviewed periodically and order is placed up to par level (S) if inventory position (on hand + on order) is below the reorder point (R) ▪ Uses maximum of usual lead time in calculations of safety stock (e.g. weekend) ▪ Calculates safety stock using the same service level for all medications ▪ Drugs are stored in dispensing machines if there is any demand in that department
2	Based on Policy 1, but uses higher service levels to calculate safety stock for more critical medications
3	▪ Uses the (M,q) model which takes into account shortage costs* ▪ The shortage cost is a cost of a stockout (extra work necessary to get the medication) ▪ Tries to balance stockout costs directly with ordering and holding costs
4	▪ Places all critical items in dispensing machines (for fast access) ▪ Uses extended lead times based on the availability and criticality of a drug ▪ For other items balances holding, restocking, waste, and filling from pharmacy through a step-by-step procedure to determine whether to store a drug in a machine and set R and S in dispensing machines for restocking and pharmacy for reordering
5	▪ Uses the same procedure as policy 4 to determine where to store drugs and how to set R and S in dispensing machines for restocking ▪ Orders from pharmacy are based on predictions of future restocking activities based on expected usage and expected waste (stochastic approach taken)

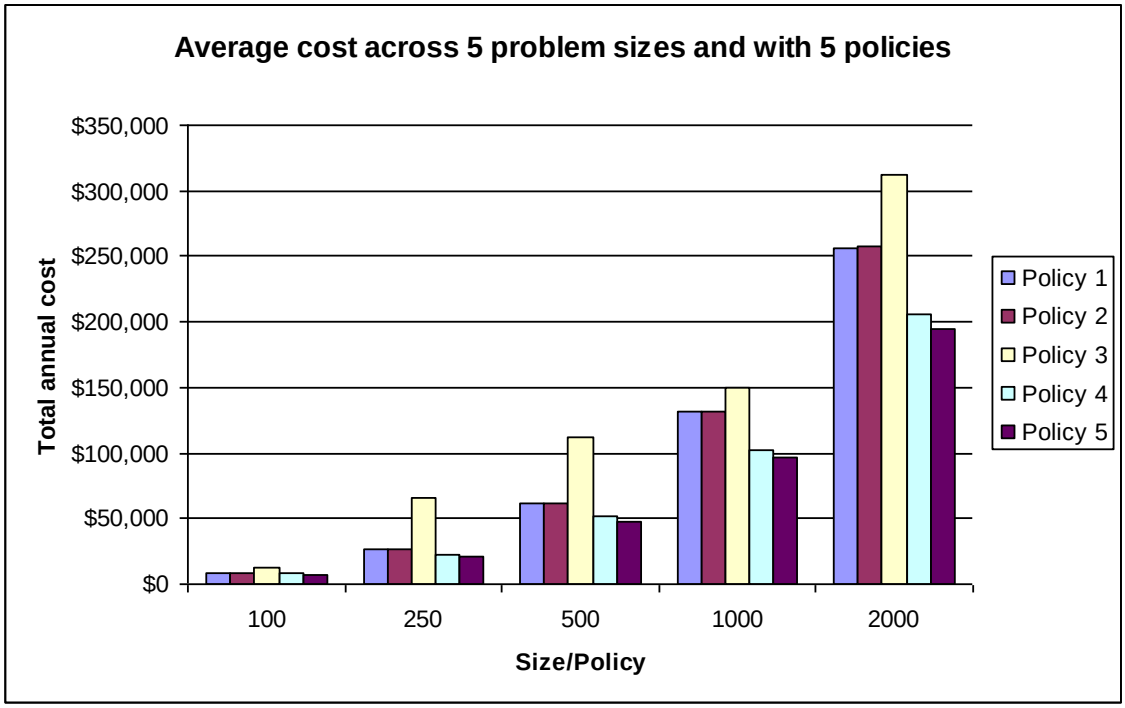
* *Winston, W.L., 2004, "Operations Research", Fourth Edition, Thomson - Brooks/Cole, pp. 868-872.*

Table 2 – Factors used in experimental design

Factor name	# possible levels	Corresponding values
Problem size (# drugs)	5	100, 250, 500, 1000, 2000
Availability level	2	1 (High), 3 (Low)
Criticality level	2	1 (Low), 3 (High)
Expiration window level	2	1 (Long), 3 (Short)
Inventory policy	5	1, 2, 3, 4, 5
Ordering frequency	1 (fixed)	5/week
Disp. machine review frequency	1 (fixed)	1/day
Expiration date review period length	1 (fixed)	30 days

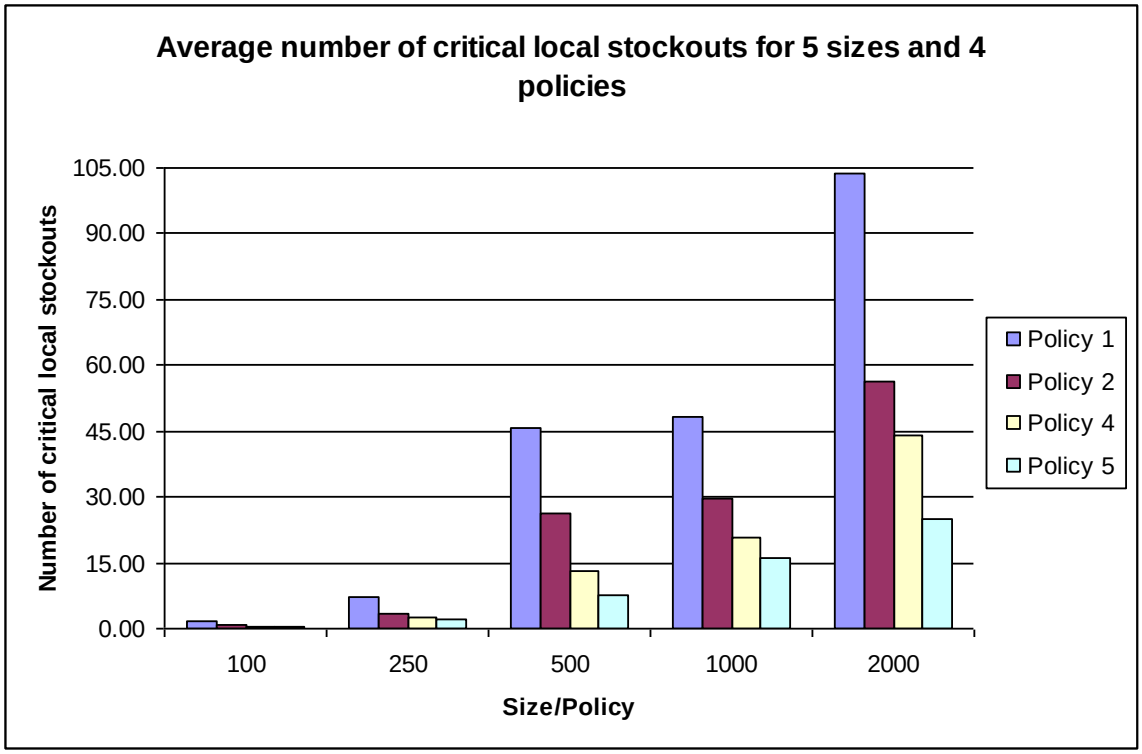
Table 3 – Explanation of performance measures (simulation output)

Performance measure		Explanation
Cost	Ordering	Cost receiving the order expressed in dollars per distinct medication
	Holding	Cost of holding inventory expressed as a percentage of inventory value
	Stockout	Cost of the additional work necessary to deal with the stockout (e.g. time to find and deliver medication from the pharmacy, or to find medication in another dispensing machine)
	Waste	Cost of drugs pulled out because of expiration date
	Restock	Cost of restocking (time spent to assemble and deliver a restock order) expressed in dollars per distinct medication per location
Stockout	Local	Situation when a drug is not available in the machine when needed
	Main	Situation when a drug for which a local stockout occurred is not available in the pharmacy
	Global	Situation when a drug for which a main stockout occurred is not available in the entire hospital (i.e. other dispensing machines)
	Critical	Stockouts (all three levels) captured for the critical drugs



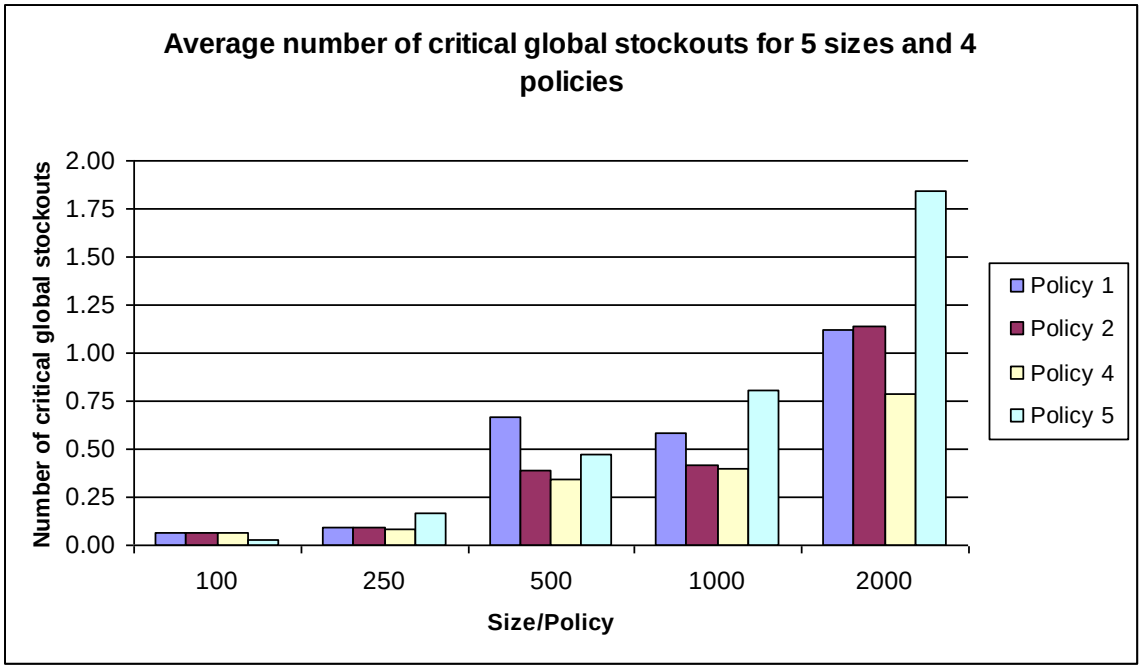
** Total cost does not take the cost of medications, cost of ordering and shipping, or the cost associated with administering drugs to patients by nurses*

Figure 4 - Cost results for different problem sizes and policies used



** Policy 3 resulted in much worse results and thus is not included in the graph*
*** Numbers represent a two-year total*

Figure 5 – Critical local stockout results for different problem sizes and policies used



** Policy 3 resulted in much worse results and thus is not included in the graph*
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Figure 6 – Critical global stockout results for different problem sizes and policies used