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Comments on “Optimal Policies for a Multi-Echelon Inventory Problem”

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It all came together on a Friday morning in mid-April 1959. Just the two of us, in a conference room at Planning Research Corporation in Westwood, CA. The paper was a direct result of this meeting. At the time, we did not think much about what impact the paper would have on future work in this area, but we are pleased and honored that it has been selected as one of the influential papers published in the 50-year history of *Management Science*.

I had been at Planning Research Corporation for just a short time after being in the Logistics Department at the RAND Corporation for five years. During my first couple of years at RAND, I helped in the design and implementation of inventory control procedures based on the Wilson lot size formula and a variable safety level concept to allow for demand uncertainty and differences in unit prices, factors not considered in the stock policies then current in the Air Force. However, I became generally disturbed that each facility (Air Force bases and a depot) was being considered independently, ignoring the fact that they were intimately connected in the real world. In particular, supply performance at the bases was being significantly degraded by lack of proper support from the depot. So, I decided to attack this multiechelon problem from an analytic point of view based on the classical AHM (Arrow-Harris-Marschak) model, particularly in order to accommodate time-dependent factors resulting from the phase-in and phase-out of weapon systems.

Starting with the most simplifying assumptions and a single-user activity supported by one higher-level facility (depot), I was able to formulate a procedure by which levels at the user facility could be determined by the AHM model, results of which were then used as inputs to a similar calculation at the depot level. With this basic approach, I was able to then consider nonzero resupply time due to the work of Karlin and Scarf and fixed reorder costs at the depot due to the work of Scarf. Also, the approach was easily

generalized to consider more than two stocking facilities so long as they were arranged in a series (each facility supplying only one next lower facility). This led to identifying the formulation as a “multiechelon” process.

This work culminated in a RAND report published in December of 1958 (RM-2247, “A Dynamic, Single-Item, Multi-Echelon Inventory Model”). Shortly after, I joined a team at Planning Research Corporation (PRC) that was doing logistics research for the Navy. Randy (J. Randolph) Simpson at the Bureau of Supplies and Accounts, Department of the Navy, was especially interested in my RAND report and was instrumental in having the PRC contract extended to accommodate further research on the multiechelon problem. In particular, the focus was on establishing whether my suggested procedure was optimal (determining stock levels that minimize inventory costs) for without such a proof, it was just another promising idea. I tried but got nowhere. Then, I heard that Herb Scarf would be coming for a week as a consultant on the various logistics projects then underway. In particular, he would have a look the optimality problem. I was delighted that he could help on this issue inasmuch as he was a leading figure in mathematical inventory theory at the time. So it was arranged for us to get together on Friday morning of that week.

I was the student, sitting at the conference table. Herb was the professor working with chalk on a blackboard. Again assuming the most simplifying conditions, he first wrote an equation for the general two-dimensional problem for base and depot stock levels. Then, he tried to separate it out into two interconnected one-dimensional problems as suggested by my previous work. As he continued, he became visibly more and more intense until he reached a point where he remarked, “I’ll be damned! It does decompose!” or words to that effect. I was having difficulty following the development and didn’t fully understand his conclusion, but I was certainly willing to accept that he had indeed solved the optimality issue. We were both happy and excited with this outcome.

Key words: inventory; multiechelon; optimal

Then Herb said he had to rush off to catch his flight back home and suggested that he could write a paper for publication. Of course, I was relieved and pleased to accept his suggestion.

The paper published in *Management Science* was written by Herb. I received his draft for review a couple of weeks after our meeting. It was written in his usual elegant style and I had few suggestions for changes except to add a brief section at the end titled “Extensions.” Publication of the paper generated a considerable amount of interest in “multiechelon” problems, with several papers appearing shortly thereafter that provided multiechelon extensions of previous results for the single-activity problem or addressed limitations of the original model. One limitation, in particular, concerned the inability to accept fixed reorder costs for all echelons except the top one. Herb investigated this problem and was able to obtain bounds for the implied shortage costs charged to next-higher echelons. This work appeared in the paper “Approximate Solutions to a Simple Multi-Echelon Inventory Problem” published as part of the book *Studies in Applied Probability and Management Science*

(1962 Arrow, Karlin, and Scarf, eds.). Although I was listed as coauthor, the paper was totally Herb’s work with my only contribution being the identification and discussion of the problem in my original RAND report.

In November of 1977, John Muckstadt at Cornell University hosted the first of what would become a series of multiechelon conferences—17 altogether extending through 1991 and conducted mostly at universities. Each conference was well attended with many interesting papers being presented on multiechelon and ancillary subjects. At the end of each conference, someone would volunteer to host the next one. For me, it was a social event as well as an academic one, and I was able to attend all of them. I’m sure that there have been other conferences since, but I lost touch after I retired. Herb and I have not been in contact until now, 45 years after publication of the paper.

Editor’s Note. The Multi-Echelon Conference is still ongoing, held on a biannual basis in conjunction with the Manufacturing and Service Operations Society Conference. The next one will be held in July 2005 at Northwestern University.