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# Summary

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## Practice-inspired contributions to inventory theory

The research field of inventory control clearly has a practical focus. The studied models and derived policies are meant to control real inventories of real companies. Yet, business practice diverges from the inventory control literature, making it questionable whether certain models and procedures are actually applicable to the scenarios in which they are used by managers and software developers. This thesis makes several contributions concerning this overarching theme. Its main contribution focuses on the practically implausible assumption that a manager has full knowledge over the probability distribution of future demand and its parameters, and the lack of a bridge with the demand forecasting literature on this topic. Furthermore, we study the possibility to decouple inventory replenishment opportunities from stock reviews. Finally, we make the well-known Repair Kit Problem more realistic by including fixed order costs and positive lead times into the model.

Safety stocks are meant to guard against the uncertainty of future demand. Proper modeling of the latter is key to making accurate inventory calculations. However, almost all inventory models proposed in the literature start from the assumption that the demand distribution and all its parameters are known, whereas in practice one only has a sample of demand observations based on which a distribution has to be fitted and parameters have to be estimated. We find that safety stocks are set way too low if such estimates are treated as true parameters, as this ignores part of the uncertainty around future demand. Furthermore, we point out that future forecast errors are correlated, which is typically ignored and leads to even larger safety stock deficits. For normally distributed demand with unknown mean and variance, we present a simple, closed-form equation to set the correct reorder level that achieves

a certain cycle service level. Thereafter, we present a general framework to include the uncertainty for every parameter estimator, every demand model, and every inventory model that can be formulated as a cost minimization problem. The exact variant requires a demand model- and estimator-specific derivation of the error distribution, but the easier applicable, approximate variant performs almost as well for sample sizes of at least 10. Especially if multiple parameters are to be estimated, such as a trend and an intercept, large cost savings can be achieved by applying the presented framework.

Many companies store their demand data periodically (e.g. weekly), whereas they manage inventories on a continuous basis. As soon as a demand causes the inventory level to drop to or below a certain reorder level, the software immediately signals that a replenishment order should be placed. The demand forecasting literature is centered around producing forecasts of future demand per period, based on historical demands per period. However, such forecasts are not helpful for fitting demand distributions at the individual customer level. We demonstrate this for the compound Poisson class of demand distributions, which is especially popular for intermittent demand. Even period forecasting methods that are designed to yield separate estimates for the time between periods with positive demand and the period demand size, are not suitable for estimating the arrival rate and demand size parameters of a compound Poisson distribution at the customer level. We find that using them as such leads to dramatically overshoot fill rates and therefore too high costs. However, also the standard method-of-moments estimator which does yield consistent parameter estimates from periodic data, still has a large bias in small samples. This leads to undershot fill rates for slow-moving demand patterns and overshoot fill rates for medium- to fast-moving demand patterns. We present a new estimator that makes explicit use of the intermittent nature of the demand and show that it has a much lower finite-sample bias than the standard estimator, which in turn yields an inventory policy that achieves closer to the target fill rate.

Moving away from the interface of demand forecasting and inventory control, we now focus on periodic review inventory control models. These are devised for companies that do not constantly have complete knowledge of their inventory, which is due to e.g. theft or misplacement, or simply periodic counting. However, a very restrictive assumption is that orders can only arrive at the same moments when a

complete stock update is received. In practice, orders can be placed at any time when the inventory policy deems necessary, and arrive after a possible lead time. We study a model where exactly this is possible; inventory updates are only made at predefined intervals, and in-between those updates only the demand distribution is known. We show that the typical order path is to first deplete excess inventory from the previous period, then build up safety stock to guard against the increasing uncertainty of the stock level, but to halt this build-up shortly before the next review, after which there is typically again an excess and the cycle repeats itself. It is interesting to observe that this policy, contrary to the standard periodic review policies, advocates to not order at or directly around an inventory review. Furthermore, because of the much smoother inventory build-up, significant holding cost savings can be achieved over standard periodic review policies.

The Repair Kit Problem aims at finding the optimal composition of an engineer's set of spare parts to carry on a tour of an unknown number of jobs that each require unknown numbers of various parts. We are the first to introduce fixed order costs and positive lead times, reflecting that some parts cannot immediately be restocked overnight and have to be shipped from elsewhere. The inclusion of this practical constraint, motivated by a real case, fundamentally changes the model and corresponding derivation of the inventory policy. We present an exact calculation of the Job Fill Rate, which measures the long-run average fraction of jobs in a tour that can directly be completed, and derive a heuristic method that optimizes the reorder level of a batch ordering policy with a fixed batch size. Whereas previous authors suggested to weigh part price and part requirement to find a good kit composition, in this scenario we suggest to trade off holding cost against service increase. We furthermore show that the EOQ provides a good solution for the batch size. After establishing the quality of our heuristic on small test instances, we apply it to the case study company and find that some engineers have a decreasing marginal fill rate gain vs. cost increase, whereas others have a marginal fill rate gain that is first increasing and then decreases again. This shows that there is a 'critical mass' of parts that are required on many jobs.

