Managing Warranty Inventory for Multi-Generational High-Tech Products

High-tech products are often multi-generational, with short product life cycles and updated versions being released on a regular schedule. In the wearable consumer electronic products industry, new product generations are introduced annually or more frequently while the warranty period may be a year or two years or even longer. Furthermore, unlike the usual practice with products such as smartphones, wherein the older generation product continues to be sold but at a discounted price when a new generation is released, manufacturers of consumer wearables often stop selling one product generation when the next one is introduced. With the increasing difficulty (and cost) of repairing wearables and similar products as electronic devices become smaller and less modular, a greater proportion of warranty claims are fulfilled using full product replacements. This leads to a challenging tradeoff: holding warranty units for each generation can be expensive due to the cost of the products and considerable uncertainty about warranty demands, but using newer-generation products to fulfill warranty claims may be even more expensive and could cannibalize demand for those products. At the center of this tradeoff is the Last Time Buy decision for the final order of a given product generation to satisfy future warranty claims, where the usual goal is to minimize the total expected cost.

In the literature, most considerations of the Last Time Buy decision have been motivated by the discontinuation of an essential component of a product by the supplier, forcing the manufacturer to decide how much of the component part to order to satisfy future manufacturing and warranty needs. In the situations that motivated our research, the manufacturer has control over both the timing and size of the Last Time Buy order, and is motivated to stop production of older generation products in order to save on costs associated with keeping the production line(s) active. For most consumer electronic devices, failure rates within the first year are below 10%.
However, with wearables, long hours of use, some of which may occur outdoors in extreme conditions, can lead to higher failure rates, particularly after the first year. Thus, the cost incurred by the manufacturer in fulfilling warranty claims can have a significant impact on the bottom line.

In our model, warranty claims may be satisfied in different ways. We assume that the manufacturer undertakes repair when it is less costly than replacement and focus our analysis on inventory to fulfill warranty claims for non-reparable units via same-generation or future-generation products. More specifically, we consider the problem facing a manufacturer of wearable consumer electronic products (or similar products) of determining the timing and size of its Last Time Buy for a newly-obsolete generation of a product. In our base model, we consider a discrete-time framework and for simplicity, assume that the Last Time Buy occurs after the final retail sale. For this reason, the manufacturer has nearly complete information about the product demand during the sales lifetime of the product. We assume that the manufacturer is able to collect accurate data on the distribution of the time to failure that captures the pattern of past warranty claims and is able to provide forecasts of future failures in the form of statistical distributions for each remaining period (or possibly as a function of the age of the product). The manufacturer incurs a fixed cost for each period it continues to produce the product. This cost represents the direct cost or opportunity cost of reserved capacity or the inefficiency penalty from keeping an older-generation product in production along with newer product(s), depending upon the situation at hand. After ending production, each unit of inventory incurs a per-period holding cost until it is used to satisfy a warranty demand. At the end of the planning horizon (time of the last possible warranty claim), any leftover units will have a (possibly zero) salvage value and any unsatisfied warranty claims will incur a penalty, which
corresponds to the cost of replacing the item with a later-generation device and any demand cannibalization effects. We seek the optimal time and quantity of the Last Time Buy with the goal of minimizing the expected cost of production, including the per-period fixed costs mentioned above, inventory holding costs, and shortage penalties due to warranty fulfillment via newer-generation products.

We characterize the optimal Last Time Buy quantity as a function of its timing and then go on to derive conditions under which the expected cost is a well-behaved function of the timing of the Last-Time-Buy. As time permits, we will report on extensions of our basic model:

• **Moral Hazard**: It is not unusual for the cost of the current-generation product plus the cost of holding it until the end of an extended warranty period to exceed the cost of the then-current product. In such cases, the optimal Last Time Buy quantity will be less than the expected number of warranty claims, so many claims may be fulfilled by more advanced generations of the product. This could lead to moral hazard problems, especially with the widespread adoption of social media: as consumers become aware that warranty claims are being satisfied using newer models of the product, they may begin to intentionally damage their devices.

• **Utilizing Product Usage Data to Reduce Warranty Claim Costs**: We also study a model with additional recourse actions, such as offering customers discounts for upgrades when their device has a high probability of failing. Such a strategy can capitalize on the now-common availability of usage data in instances where the failure rate is increasing with cumulative usage. We explore methods for utilizing this data for failure prediction, as well as the related decision of when to offer an incentive to upgrade.