The facts on the ground:
using simulation to understand policies in humanitarian fleet management

The complex settings of humanitarian relief operations have inspired considerable analytical work on optimal decision-making. However, implementing these analytical results in the field has proven more challenging. Empirical evidence shows (Eftekhar & Van Wassenhove 2016) that field managers do not follow standard policies recommended by researchers or international agencies, because “what seems logical from the headquarters’ perspective may be illogical or inconvenient for the field.” In our work, we encountered similar statements expressed by logistics officers and fleet managers. To give a specific example, one large international humanitarian organization (LIHO) recommends that field managers sell or dispose of vehicles once they are used for either 5 years or 150,000 km, whichever comes first. The consensus among our interviewees, however, was that field managers do not follow this policy. Our goal is to find empirical and counterfactual evidence that explains such discrepancies.

The main contribution of our work is a holistic simulation environment that models and evaluates the acquisition, assignment, and disposition of multi-attribute vehicles in field operations. The economic performance of a given policy (e.g., a disposition policy) is determined by complex interactions between the fleet composition, the “demands” (humanitarian missions) on the fleet, and the depreciation of the fleet over time. These interactions are too complex to allow any tractable analytical treatment. However, one can use simulation to evaluate and compare various policies in a realistic setting. Simulation has been used in this way to study policies for many public-sector problems, such as HIV/AIDS prevention (Rauner, 2002) and emergency response (Kaplan et al., 2002).
Policy evaluation in humanitarian logistics is difficult because both vehicles and demands possess heterogeneous attributes. For example, vehicles are acquired at different times, and their individual ages and odometers not only affect their operating costs, but also change dynamically over time. Our simulator models these dynamic attributes and evaluates their impact on cost, using data from LIHO on fleets of multi-attribute vehicles in several offices where missions have very different attributes. Specifically: 1) We treat odometer data as a (censored) stand-in for demand, and develop a stochastic model of non-stationary, attribute-dependent demands over time. The simulated demand trajectories follow the same overall trend as what was observed historically, but may deviate significantly from historical data at any given time. 2) Salvage data are used to calibrate a statistical model for the depreciation of vehicles as they are exploited; a vehicle is removed from the fleet once it has lost all of its value, but can be sold earlier to redeem a portion of that value. 3) Purchase and maintenance data are used to calibrate statistical models that calculate purchase, fuel and maintenance costs as a function of vehicle attributes.

Using simulation to combine these models, we evaluate total operating costs incurred over several years, under various candidate policies for purchase, assignment, and disposition. We give two examples of practical problems where our study provides new insight:

1. *Salvage policies.* We compared LIHO’s recommended 5 year/150,000 km disposition policy with other age/odometer thresholds, and consistently found that this policy was too quick to dispose of vehicles. The best threshold does become lower as the load on the fleet increases. However, even for very high loads, vehicles can be used for as much as 225,000 km. This behaviour is caused by a nonlinear relationship between age/odometer and depreciation.

2. *Mission switching.* In practice, LIHO assigns each new vehicle to a particular mission type, and does not change this assignment for the remainder of the vehicle’s lifetime. We analyzed
policies that allowed vehicles to switch types, but found (surprisingly) that the benefit of switching is marginal at best, even in artificial “off-sync” scenarios where demand for one type increases just as demand for another type ramps down. Switching saves purchase costs by using a smaller fleet, but the resulting increase in fuel and maintenance costs (due to exploiting the vehicles more heavily) virtually negates this benefit.

These results help us understand why fleet managers make decisions the way that they do. In practice, assignment and disposition decisions do not appear to be based on any specific policy; nonetheless, managers’ intuitive perception of the situation, based on their experience or other factors, may lead them to reject policies that are clearly suboptimal, such as LIHO’s disposition policy. Likewise, the value of coordination in logistics is well-established, and one expects that mission switching would improve efficiency; however, the lack of any such improvement seen in our simulation results helps to explain why, in the field, switching is not widely practiced or even encouraged. Beyond these insights, our simulation-based approach offers researchers a way to handle the complex dynamics of humanitarian logistics problems with greater modeling granularity than existing stylized models from the literature.

References

