Research Statement

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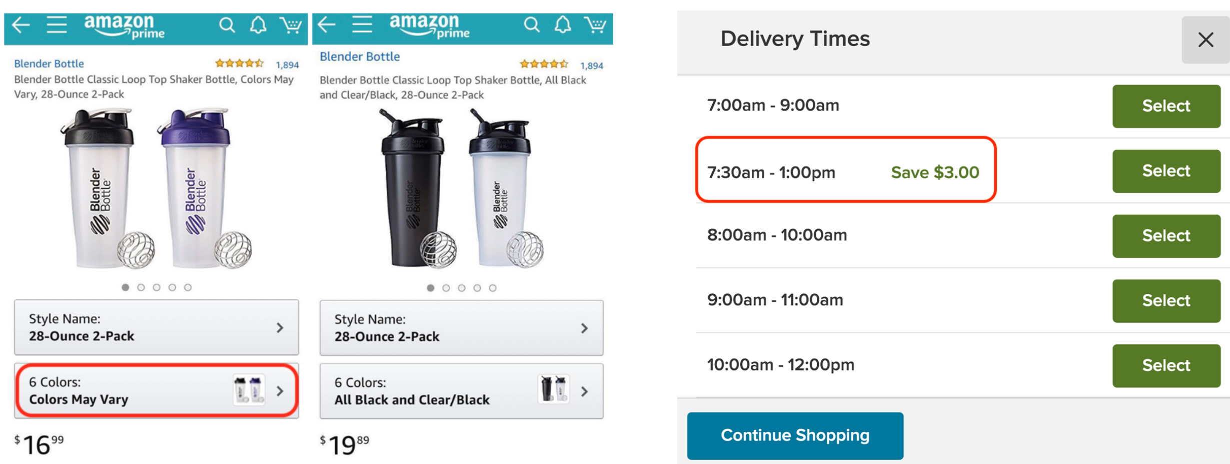
My research centers on simple and flexible strategies in supply chain management and service operations. My goals are to develop (near) optimal, implementable policies to generate clear guidelines for decision making in important operations problems. In my doctoral research, I mainly focus on two topics: (1) a new notion of flexibility that has emerged in online platforms, and (2) simple-to-implement strategies for complex operations problems. Below, I provide an overview of my research by discussing my completed and working papers.

Consumer Flexibility

In the highly competitive online marketplace, retailers and service providers are tempted to increase the number of options offered to maximize the chance of a purchase. However, it comes with a fundamental tradeoff between increasing the number of options and the difficulty in managing the inventory/capacity. To address this fundamental tradeoff, I have studied an innovative concept, ***consumer flexibility***, which we define as a consumer's explicit willingness to receive one of multiple options, in exchange for a reward or discount.



Note. On the left, the "Colors May Vary" option is an opaque product on Amazon.com. On the right, the "7:30am - 1:00pm" is a large time window on Peapod.com. Both flexible options are sold with a discount.

The figures above show two examples of consumer flexibility, (1) an opaque product in online retailing, and (2) a large time window in online service platforms. Online retailers can leverage consumer flexibility through opaque products, which is defined as a product where some specific attributes are not revealed to the customer until after purchase. The retailer can utilize consumer flexibility to balance inventory levels and reduce supply chain costs. In online service platforms (such as healthcare, home maintenance, and grocery delivery), a customer makes an appointment by choosing one option from a list of regular time windows. Consumer flexibility can be realized through large time windows, which are composed of multiple regular time windows. Customers that offer time flexibility allow the service providers to better utilize their service capacities.

The main findings from this research stream are on the power of limited flexibility, which is the exceptionally good performance using simple flexible options with just a small fraction of customers willing to be flexible. These findings have practical managerial implications, as achieving full flexibility is practically infeasible since it would require substantial incentives by the firm to materialize. Our results are in line with the well-known principle that "a little flexibility goes a long way", but now we have shown this when the demand — rather than supply — is flexible.

As a starting point, we study a model with two substitutable products and an opaque product. In ***"Retailing with Opaque Products"*** [1] (Major Revision at *Manufacturing & Service Operations Management*), we use average cost dynamic programming to analyze policies for opaque product allocation and we use a Markov chain analysis to study the value of consumer flexibility that underlies opaque products. We show that selling opaque products can be done using a simple inventory-balancing policy and can yield substantial profit increases for online retailers. Moreover, this advantage only requires a relatively small fraction of customers to purchase opaque products.

In ***"The Value of Flexibility from Opaque Selling"*** [2] (Major Revision at *Management Science*), we extend our study to a more general multi-product joint replenishment problem with opaque products. In this setting, consumer flexibility is leveraged through a k-opaque option where customers select k products from which the seller allocates one to the customer. As the techniques in the two-product case cannot be generalized, we tap into a novel connection between opaque selling and the balls-into-bins framework. We find that even with limited flexibility, i.e., offering 2-opaque products and with only a small fraction of customers being flexible, the seller can achieve significant inventory cost savings, which is on the same order of magnitude as the cost savings from a fully flexible scheme. Moreover, our study provides practical guidance to retailers that the first-order effect comes from adopting opaque products with a small incentive, while re-optimizing the inventory policy only provides a second-order value.

In the context of online service platforms, we also demonstrate the power of limited flexibility with a simple large time window design and only a small fraction of customers choosing the large time windows. In ***"The Value of Consumer Flexibility in Scheduled Service Systems"*** [3] (working paper), we analyze the capacity pooling benefit using large time windows. We demonstrate that there are diminishing returns to the increased fraction of customers being flexible, and the benefit of a limited flexible design where large time windows are composed of two consecutive regular time windows can capture most of the total capacity pooling benefit. In particular, we investigate the large time window design in a long chain structure. In the process flexibility literature, it is well-known that incrementally adding flexibility has increasing returns (supermodularity), and as a byproduct 'closing the loop' provides the most benefit. We found that supermodularity does not hold in our model, and that 'closing the loop' typically provides the least value in time window design. The lack of supermodularity in our setting is a rather fortunate outcome, as a high capacity utilization can be achieved without offering too many choices.

A win-win situation comes out of consumer flexibility: a customer who chooses the opaque product/large time window receives a discount, while the firm gains significant benefit in operations through a simple limited-flexible strategy. Furthermore, my research highlights a fundamental difference between demand-side flexibility (consumer flexibility) and supply-side flexibility (process flexibility). However, little attention has been paid to the demand-side flexibility, while the importance of flexibility on the supply side has been extensively studied. I am thrilled to continue exploring the value and implementation of consumer flexibility in some interesting directions including the operations of ride-sharing and online grocery platforms.

Other Research Projects

A key issue in operations management is to provide theoretical support to practical heuristics, which are necessary when the optimal strategy is computationally challenging or hard to implement. For instance, the optimal dynamic policy for the joint pricing and inventory management problem is generally hard to find, and the implementation may not be feasible due to business constraints. In my preliminary work ***"Static Pricing Guarantees for Joint Pricing and Inventory Management"*** [4], we construct a static pricing policy that only increases inventory costs by a constant factor while actually increasing revenue, in comparison with the optimal dynamic pricing policy. To the best of our knowledge, this is the first result that provides performance guarantees derived on the strength of static pricing for this class of problems.

In another recent work ***"Queuing Safely for Elevator Systems amidst a Pandemic"*** [5], we propose multiple effective and implementable policies for safely managing elevator systems amidst a pandemic, in collaboration with the New York City Mayor's Office. COVID-19 has dramatically altered our life, and a safe reopening plan requires careful mathematical modeling. In particular, significant challenges and concerns arise in high-rise buildings as the social distancing rule has drastically reduced elevator capacity, which will cause long queues in a limited lobby space. To address this issue, we have built a detailed mathematical framework and simulation model to evaluate proposed policies using data from a large NYC building. Due to the fact that many government buildings in NYC are historical buildings with outdated technology, the policies we propose do not require any programming of the elevators and only manage passenger behavior by cohorting passengers into more efficient travel groups. Our cohorting policies can easily be implemented in any building. A pilot program is in preparation based on our simulation results.

Future Directions

Moving forward, my vision is to continue using analytical tools to design easy-to-implement strategies and improve operations. My short-term goals include further exploring the value of consumer flexibility and deriving data-driven algorithms to utilize consumer flexibility, specifically in on-demand service platforms with real-time decision making. In the long term, I plan to continue my research in operations management to provide key insights in fundamental problems such as pricing, inventory management, and logistics. Furthermore, I am interested in expanding my research into broader directions that incorporate consumer data, such as product reviews, into operational decisions. In my recent work ***"Herding, Learning, and Incentives for Online Reviews"*** [6], we develop a model in which customer reviews affect the demand of a product both through herding and learning effects and compare several incentive schemes for customer reviews. I plan to continue exploring the impact of customer reviews on operations and revenue management through various perspectives such as social learning and choice modeling. I am confident that my academic background and research experiences have positioned me to be at the forefront of using rigorous theory to produce insightful research and create effective operational strategies.

References

[1] A. N. Elmachtoub, Y. Wei, and Y. Zhou. 2020. Retailing with Opaque Products. Major revision in *Manufacturing & Service Operations Management*.

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[3] A. N. Elmachtoub and Y. Zhou. The Value of Consumer Flexibility in Scheduled Service Systems. Working Paper.

[4] A. N. Elmachtoub and Y. Zhou. Static Pricing Guarantees for Joint Pricing and Inventory Management. Work in Progress.

[5] S. M. Ananthanarayanan, C. C. Branas, A. N. Elmachtoub, C. Stein, and Y. Zhou. Queuing Safely for Elevator Systems amidst a Pandemic. Submitted.

[6] R. Kohli, X. Lei, and Y. Zhou. Herding, Learning, and Incentives for Online Reviews. Submitted.