An Agent-Based Modeling Approach for Informing the U.S. Plastic Waste Management Process

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Presenter Bio

Yuanhui Huang

- B.S. in Computer and Information and Technology at Purdue University (May 2021)
- Currently a graduate student at the Department of Computer Science, Northwestern University
- Research Interests: HCI in areas of wearable technology, mental health, and affective computing
- This research was performed as an undergraduate student at Purdue.

Agenda

- Introduction
- Background
- Research Method
- Experiments and Results
- Conclusion
- References

Introduction

Plastics consumption increases every year but there is little improvement in plastics recycling rate

- Only **9%** was recycled, **12%** was incinerated, and **79%** was deposited in landfills or discarded in natural environments, such as the oceans [1][2]
- Without proper treatment
  - Plastic debris can physically harm wildlife
  - Debris breaking into smaller pieces can infiltrate food webs [4]
- Difficulties in dealing the plastics waste
  - Hugely expensive[3]
  - Negative impacts on the environment [4]
  - The outbreak of COVD-19 [5][6]

Introduction

The current plastic waste management system needs better approaches to deal with these large numbers of post-consumer plastics. However, it remains unclear what interventions will best support plastic waste management.

Research Question

- How do strategies, such as an education campaign and a system-wide improvement influence the plastics waste management system behavior?

Background

Plastics Waste Management Framework

- Plastics' low cost, lightweight, and versatility has a vast area of use in industries [8].
- A given plastic piece can only be recycled 2 to 3 times on average[10].
- The requirements for successful plastic recycling [11]:

  Proper infrastructure to collect the waste

  Available technology to reprocess the waste into secondary products economically

  Developed markets for the cost-effective use of recycled products

Background

Recyclable Plastics and non-recyclable plastics

- Recycling - the process of converting waste materials into new materials

- Plastics have **different recyclability** depending on polymer types, legislative requirements, product lifetime, and other variables [12]

  Impurities take up **28%** of plastic waste

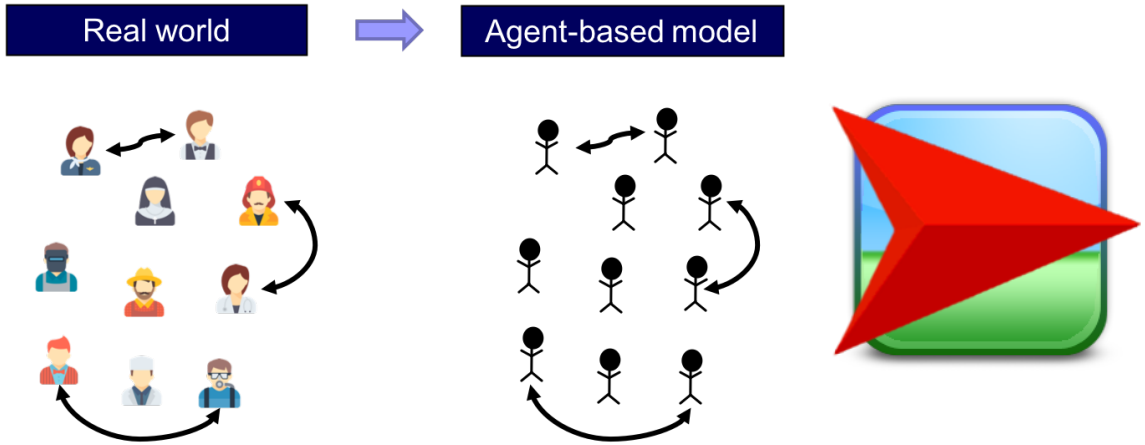
  Around **75%** of the plastics waste are considered as Low-Quality applications

  The recyclability of "Low-Quality" plastic waste is **12% to 35%** lower than those categorized as "high-quality" plastics waste

Background

- Agent-based modeling and simulation (ABMS) is a computational modeling approach applied to the term "agent" to describe complex processes, behavior, and phenomena [23]
- Unlike other conventional modeling tools, Agent-based modeling responds to the environment actively [24]
- NetLogo, a multi-agent and modeling environment, can simulate natural and social phenomena [26].

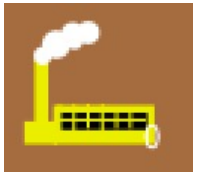
Four types of agents make up NetLogo: **Turtles, patches, links, and observers**



Research Method

As the detailed investigation of plastic waste lifecycle can be time-consuming and expensive, NetLogo may be an efficient tool to estimate one action's outcomes.

Plastics
plastics wastes generated by the households



Center
Recycling facility that performs the recycle

Houses
The number of households in a community

Research Method

Simulation Workflow

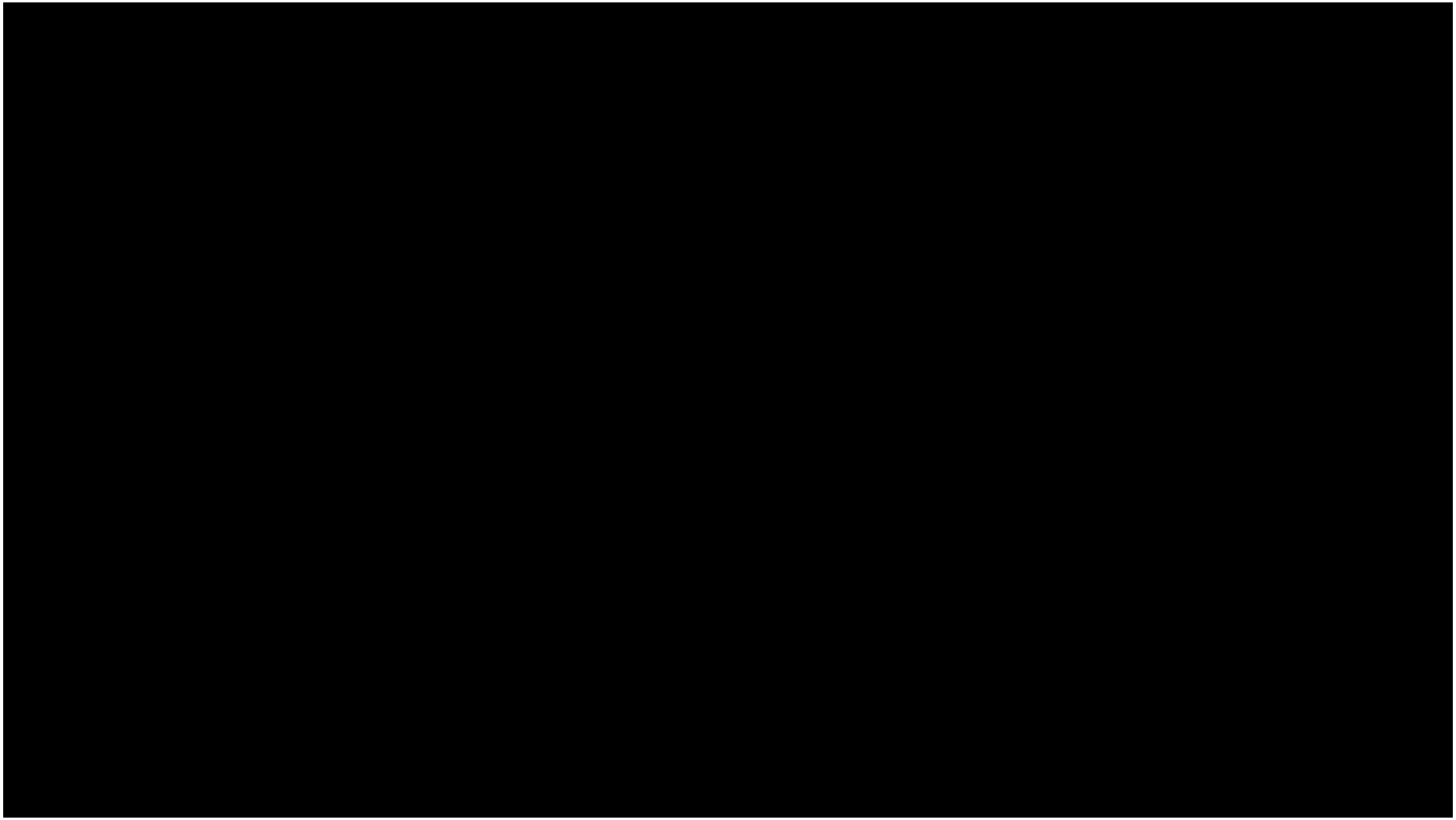
Landfill - The amount of plastic waste (in kg) is ended up in a landfill.

Collect - The amount of plastic waste (in kg) has been sent to the recycling center.

Recycle - The amount of plastic waste (in kg) has been sent to the recycling center and has been recycled in the system.

New plastics - The amount of plastic waste (in kg) becomes secondary products.

Research Method



- https://youtu.be/Sa12R_RWQyY

Simulation Experiments and Results

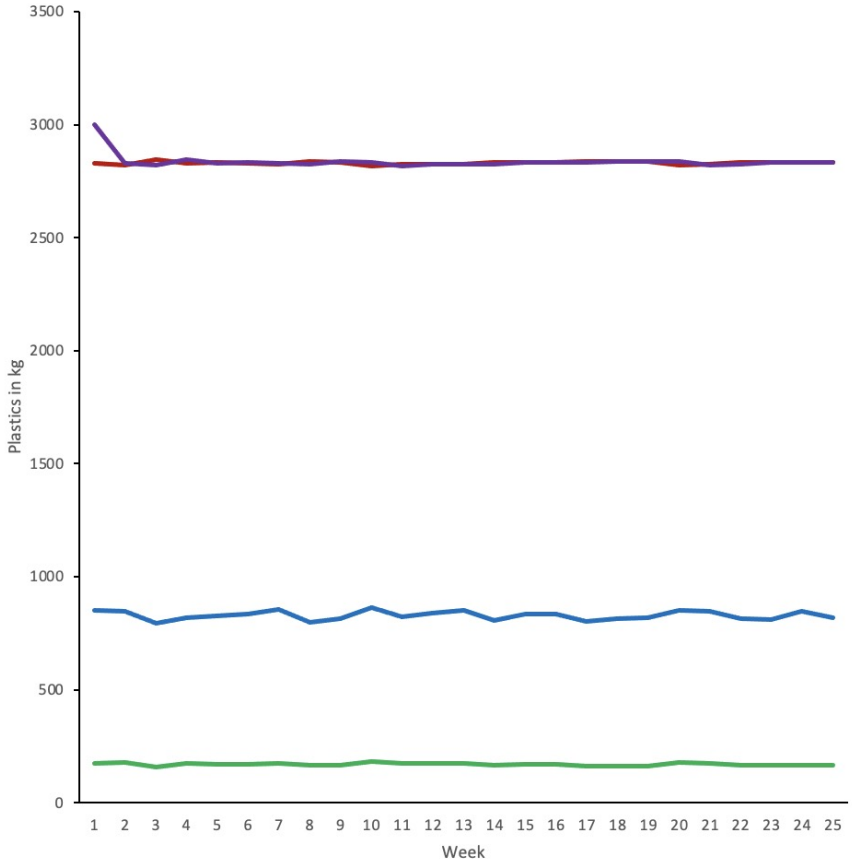
Feasibility Testing

- The feasibility testing used data from the American Chemistry Council and the National Association for PET Container Resources

  The average simulated recycling rate is 8.97% for ten weeks run, and this result has less than 0.5% difference with the PET Container Resources data in 2018 (8.66%).

Simulation Experiments and Results

Construct a baseline scenario



- All scenarios data were retrieved the mean from 10 repetitions run

- Each scenario recorded the recycled, collected, landfill, and total generated plastics amount in 25 weeks

- All scenarios were adjusted according to the baseline parameters to evaluate the effect of customer behavior changes or system-level improvements.

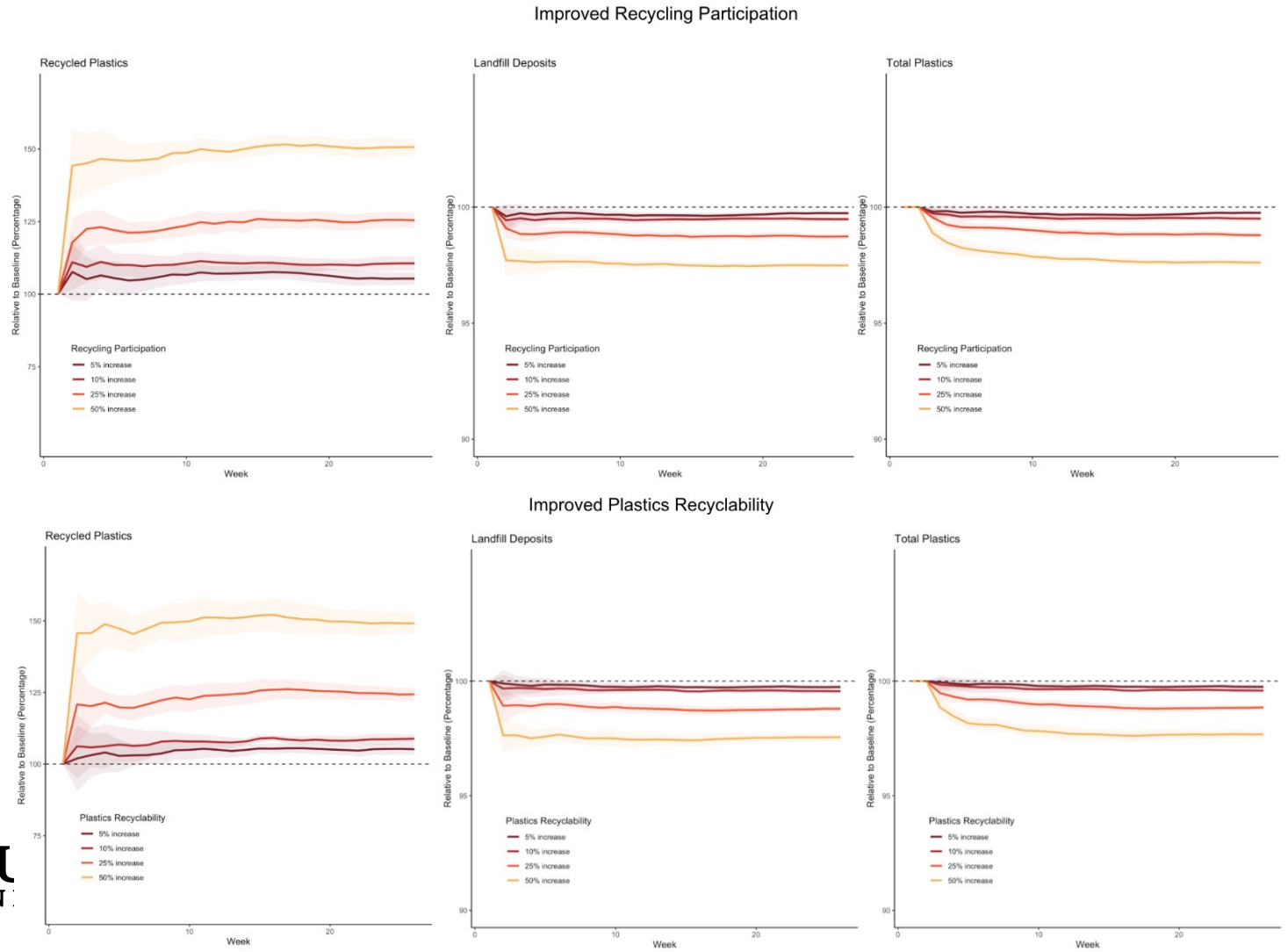
Simulation Experiments and Results

Experiment 1: Effect of an Education Campaign

- Education can make more people decide to recycle, or it can make them recycle more effectively and adequately.
- We looked at the effect of 5%, 10%, 25%, and 50% improvements on plastics recyclability and recycling participation from our baseline, reflecting the increased sorting and recycling behaviors.

Simulation Experiments and Results

Experiment 1: Effect of an Education Campaign



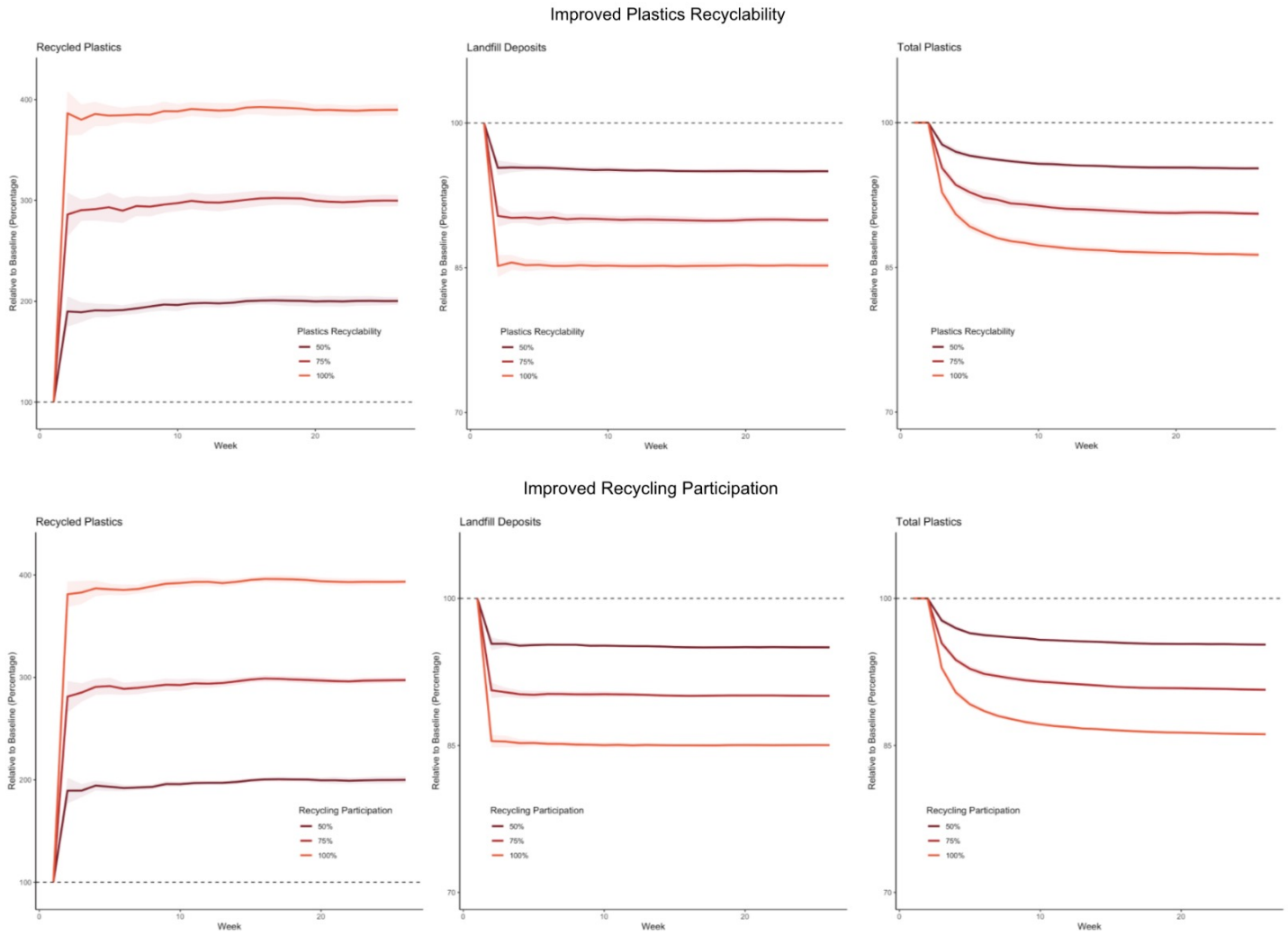
Simulation Experiments and Results

Experiment 2: Effect of System-wide Improvement

- Improved recycling infrastructure can handle a broader set of plastics.
- This experiment examined potential system-wide improvement based on technological changes, infrastructure investments, or policy implementation that may boost recycling participation and plastics recyclability.
- We tested the plastics recyclability and recycling participation scenarios when they were 50%, 75%, and 100% (Hypothetical maximum)

Simulation Experiments and Results

Experiment 2: Effect of System-wide Improvement



Conclusion

Approaching this system-level problem in a one-dimensional way is insufficient. Simply altering individual behaviors through education has limited effects on the system.

- Education, technology, and infrastructure changes should all be carried out to ameliorate the plastics waste management problem.

Limitations and Future works

- Plastics types
- Hard to record recycle participation
- The limitation of household amount
- Incineration process

Thank you!

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