Crossing Paths

Designing Trust Between Humans and Delivery Robots:
A design-led exploration of public-space interaction

Trust as 'Infrastructure' in Human–Robot Futures

As autonomous systems become ubiquitous in our built environment, design must evolve beyond its human-centric foundations. This project explores relational design for autonomous futures, examining how trust is formed, negotiated, and sustained between humans and anthropomorphized technology.

This study sits at the intersection of human-robot interaction and behavioral design, contributing to an emerging field that will only grow more critical as autonomous systems scale from isolated deployments to integrated networks. Just as mobile-first design emerged with the rise of smartphones, we now require design approaches that recognize autonomous agents as co-inhabitants of our sidewalks, interfaces, and systems.

Trust between humans and robots is infrastructural. Delivery robots on sidewalks offer a critical lens into this dynamic because they operate in the messy reality of public space, where design choices immediately impact whether coexistence succeeds or fails.

What ✸ designers need to know

At its core, this is a playbook for design practitioners working with autonomous and anthropomorphized systems. Instead of forcing robots into human-centered frameworks, we need to rethink how we design for human-robot ecosystems, treating both as primary users.

The insights surfaced here extend far beyond delivery robots. They're foundational for any scenario where autonomous systems must coexist with humans as peers—from warehouse robots and robotic pets to autonomous vehicles and future forms we haven't yet imagined.

Research Credits

This research is an independent study conducted by Shreya Mathur at the Institute of Design, Illinois Tech. Shreya is a Master of Design graduate student in the class of 2026. With prior experience in user experience design, she integrates behavioral design, design strategy, and systems thinking through her coursework at the Institute.

She is advised by Ruth Schmidt, an Associate Professor at the Institute of Design specializing in behavioral design. Professor Schmidt's work blends humanity-centered design, systems design, and behavioral science to address behavioral challenges in a more systematic and equitable manner.

GOAL

Independent Study: **Report**

2025

The goal of this work is to explore how trust emerges from everyday encounters between humans and robots in shared environments, and what ✦ design choices can foster relationships that sustain coexistence.

Using sidewalk delivery robots as a concrete example, this project surfaces design insights for building trust in autonomous technology.

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Building Context

Sidewalk robots need more than *intelligence*

The study began by exploring how technology has shaped human life and examining the evolving meaning of autonomy in today's world. Autonomy was once a quality unique to living beings, but in the last 20 years we have created sophisticated products that possess their own intelligence, goals, and methods for interacting with the world.

Delivery robots aren't going anywhere

Delivery robots navigate sidewalks, negotiate pedestrian traffic, and make decisions about routes and timing, all without human intervention in the moment. They've been around long enough that seeing them isn't entirely foreign anymore. But we're at an inflection point. With companies like DoorDash launching their own delivery robot (Dot) as recently as September 2025, and UberEats continually expanding its robot partnerships in various cities, we are transitioning from pilot programs to defining infrastructure. Which means we need to examine our relationship with these robots. What does trust look like in this context? How can we design interactions that work for everyone?

The ✸ gap that remains

Technical autonomy is progressing rapidly, with companies like Starship and Kiwibot making robots smarter and more capable. However, the relational layer—how humans interpret robotic behavior and develop trust remains largely unexplored. This imbalance highlights a critical design gap in understanding how to foster trust, empathy, and coexistence. This study seeks to address that gap.

> "The construction of a technical system that involves human beings as operating parts brings a reconstruction of social roles and relationships.
>
> **Langdon Winner,** philosopher of technology
> The Whale and the Reactor (1988)

Autonomous delivery is only set to grow

2.5x

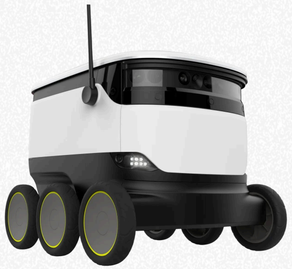
Growth projected: market expanding from $1.11 billion (2025) to $2.8 billion (2030)

Mordor Intelligence Report - Autonomous Robots Growth Forecast

2M

total units (2028) projected, expanding 4x from 500,000 units (2024)

Market Report Analytics - Delivery Robots Market Ecosystem



Starship is the industry leader in autonomous delivery with:

12 Million
Miles driven

9 Million
Deliveries completed

270+
Global locations
Cities, campuses, industrial sites

As of November 2025 - starship.xyz

02

Research
Review

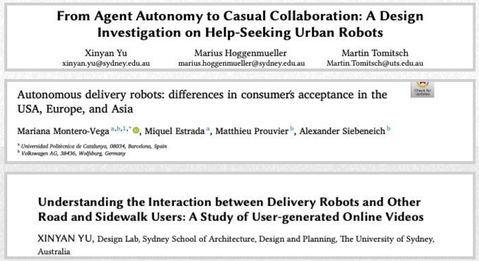
Existing knowledge *shaped* the study

To understand trust in human-robot interactions, two complementary perspectives were needed: what formal research tells us about how these relationships should work, and what's actually happening on sidewalks right now.

The literature review grounded the study in established frameworks around human-robot interaction and behavioral design. It provided theoretical foundations for understanding what makes autonomous systems legible and trustworthy.

Social media analysis captured unfiltered, real-time reactions from people encountering delivery robots in their daily lives. Platforms like Reddit, TikTok, and Instagram revealed spontaneous emotional responses, emerging social norms, and the actual behaviors people exhibit when they share space with robots.

Together, these methods allowed me to examine trust both as a design construct and as a lived social phenomenon.


From Agent Autonomy to Casual Collaboration: A Design Investigation on Help-Seeking Urban Robots

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Autonomous delivery robots: differences in consumer's acceptance in the USA, Europe, and Asia

Mariana Montero-Vega, Miquel Estrada, Matthieu Prouvier, Alexander Siebeneich

Understanding the Interaction between Delivery Robots and Other Road and Sidewalk Users: A Study of User-generated Online Videos

XINYAN YU, Design Lab, Sydney School of Architecture, Design and Planning, The University of Sydney, Australia

Literature Review

Latest published research was examined to discover:

- Human-robot interaction design and acceptance
- Consumer attitudes toward autonomous delivery across regions
- Behavioral factors influencing adoption and trust
- Technical and social dimensions of sidewalk robot deployment

Links to these papers in the appendix

Social Media Analysis

Posts, comments, and videos were analyzed to surface:

- Spontaneous emotional reactions (curiosity, delight, skepticism)
- Informal social norms around sidewalk robots
- Real-world behaviors and interactions
- Emerging patterns in what people expect from these robots

Six key *insights* emerged from the desk research

Action transparency is critical

Studies emphasize that reliability, predictability, and transparency in a robot's actions (e.g. clearly signaling its next move) are essential to cultivating user trust. Consistent performance and honest, clear communication from an AI agent significantly improve people's willingness to engage with such systems.

Anthropomorphic design influences response

Adding human-like features (expressive "eyes," voices, names) makes robots more relatable and approachable, increasing positive engagement. However, designers must balance anthropomorphism carefully; overdoing it can undermine functionality and create unrealistic expectations about the robot's capabilities.

Clear signals enable safe interactions

Delivery robots that explicitly signal intent (through digital displays, turn signal lights, or projected arrows) are easier for pedestrians to understand. Clear communication improves comfort and safety in shared spaces. Well-designed cues such as sounds, lights, and screens, act as affordances that help humans predict what the robot will do next.

People develop empathy toward robots

Field observations show bystanders voluntarily helping stuck or malfunctioning delivery robots. Pedestrians have assisted snow-stuck robots, perceiving them as cute, helpful, and in need of rescue. They're also seen cheering these robots on. This suggests humans can develop empathetic responses toward robots, treating them somewhat like strangers who occasionally need help.

Not all human-robot encounters are positive

Real-world deployments reveal resistance beyond simple curiosity. People kick, tip over, or vandalize delivery robots on sidewalks. This antagonism often stems from tech-gloom anxieties when it feels too novel or dystopian and raises fears about job displacement. Some view robots as unwelcome intruders in human spaces. This resistance highlights that technical readiness doesn't guarantee social acceptance.

Safety, accessibility, and equity concerns persist

Pedestrians worry about collisions, tripping hazards, and unpredictable behavior. But accessibility issues run deeper: robots can block pathways for wheelchair users, remain undetectable to blind pedestrians, or fail to accommodate those with mobility limitations. What works for able-bodied pedestrians may create barriers or risks for others, amplifying existing inequities in public space.

Core experience constructs that shape the relationship

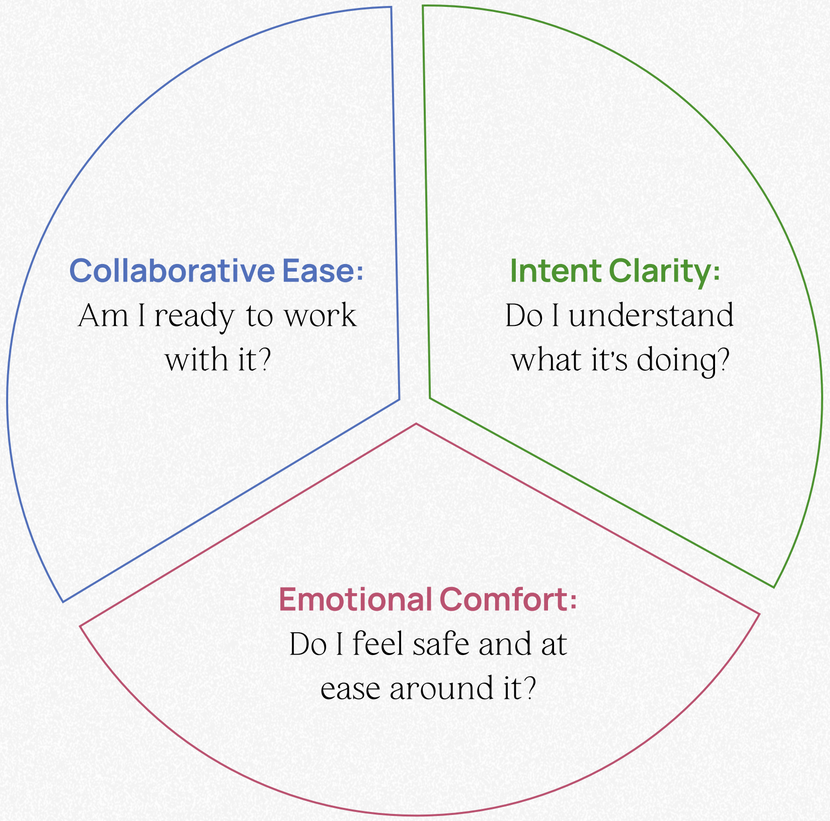
The insights from the desk research revealed patterns in how people respond to delivery robots. Across insights, moments of ease, confusion, and discomfort consistently clustered around similar breakdowns in understanding intent, coordination, and emotional response.Three distinct dimensions of human experience emerged from analyzing these interactions:

Collaborative Ease: Am I ready to work with it?
Knowing the robot will adapt and make interaction easy.

Intent Clarity: Do I understand what it's doing?
Understanding robot's purpose, goal, and next move.

Emotional Comfort: Do I feel safe around it?
Feeling safe, at ease, and positive in the robot's presence.

These constructs aren't isolated, but instead overlap and reinforce each other. A robot that signals clearly (Intent Clarity), makes interactions smoother (Collaborative Ease), which in turn makes people feel safer (Emotional Comfort).



Cross-context

While surfaced through delivery robot interactions, these constructs reflect broader, well-documented human responses to autonomous and anthropomorphized systems, making them applicable across contexts where non-human agents operate alongside people.

Navigating emerging tensions in *shifting perspectives*

Trust isn't automatic and is earned through legibility, predictability, and familiarity over time. This process is rarely linear. Instead, trust emerges through ongoing tensions in how people perceive and interpret autonomous behavior, requiring designers to account for uncertainty, hesitation, and misalignment as integral parts of the experience.

People are simultaneously curious and cautious, empathetic yet resistant. The relationship is shifting from novelty to normalization, but that transition is uneven and fraught with contradictions. What emerges is a complex social dynamic where robots must prove themselves worthy of sharing public space, while humans grapple with what it means to coexist with autonomous agents that don't fit existing social categories.

Curiosity Meets Resistance

Delivery robots spark curiosity, but curiosity coexists with skepticism and outright resistance. Some see them as fascinating glimpses of the future; others view them as dystopian intrusions or unwelcome changes to public space. This tension reflects that cultural acceptance lags behind technical deployment. Novelty generates engagement, but it also generates anxiety about what these robots represent.

The Anthropomorphism Paradox

People respond positively to human-like features such as expressive eyes, friendly sounds, names. Anthropomorphism makes these robots more approachable and relatable. But there's a limit: too many human-like features create doubts about its capabilities. People want robots legible enough to understand but functional enough to remain tools. The sweet spot is somewhere between purely mechanical and overtly human.

03

Design
Reframing

The shift in thinking that *shapes* these relationships

We have been designing robots, interactions, and user experiences. But designing for trust requires a different way of thinking—one that centers behavior, affordance, and interaction as relational forces rather than just interface features. Existing principles from human-robot interaction offer a foundation. However, translating these abstract principles to new contexts demands concrete behavioral and interaction design choices.

An abstract relationship such as trust — emerges from — **Concrete design choices that enable it**

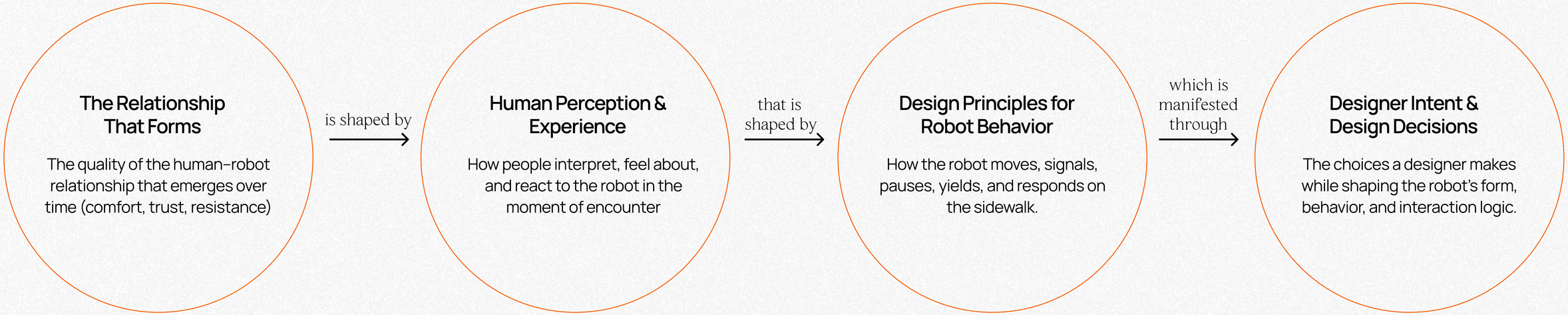
What we know: The desired outcome

What we need to learn: Design principles

This gap is bridged by solving for the three core experience constructs

In the context of delivery robots, this means:

Trust is an outcome of human experience. This reframe proposes a way of approaching trust as a design problem. Rather than treating trust as an abstract goal, it can be addressed by tracing how designer intent translates into robot behavior, how that behavior shapes human perception in the moment, and how these moments accumulate into a relationship over time. This perspective offers a concrete path for designers to move from desired outcomes to actionable design decisions.



To formulate design principles , we need to learn:

What robot behavior patterns create ✦ positive human experiences ✦ across the dimensions of Collaborative Ease, Intent Clarity, and Emotional Comfort?

Using a questionnaire as a study instrument

To ground the three experience constructs in lived responses, I conducted a questionnaire study with 30 participants aged 25–40 across cities including Chicago, New York, Bangalore, San Francisco, Toronto, Madrid, and Delhi . Running from November 12 to November 24, 2025, the study captured how people interpret and react to delivery robot behaviors across a range of encounters.

Four probing areas based on the constructs

01 **Behavioral Expectations & Social Integration**
Understanding what behaviors people expect from robots

02 **Help Signaling & Collaborative Willingness**
Measuring how people respond to robots that need help

03 **Anthropomorphic Features & Affective Connection**
Assessing preferences for human-like traits

04 **Assumed Comfort Levels**
Capturing baseline comfort with robot presence

Measuring what ✸ matters

The questionnaire enabled the constructs to be examined in concrete encounters. By translating Collaborative Ease, Intent Clarity, and Emotional Comfort into measurable prompts, the study made it possible to compare how different robot behaviors influence human experience. This highlighted which behaviors support trust and which introduce friction.

Insights from the questionnaire results supported in designing the framework.

04 Conceptual Framework

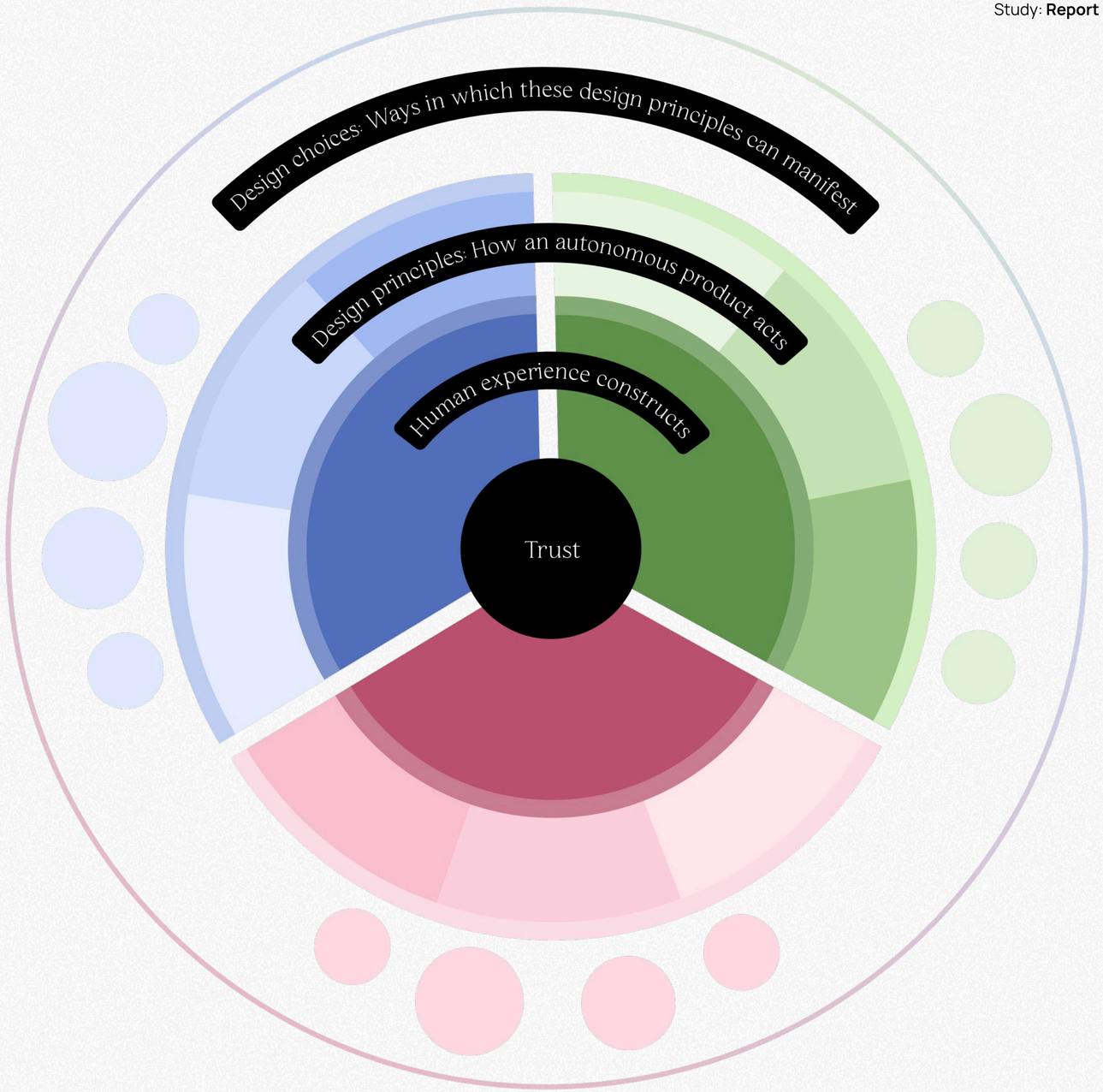
Translating the insights into a framework

Reading the framework

This framework operationalizes trust by breaking it down into three human experience constructs—Collaborative Ease, Intent Clarity, and Emotional Comfort.

Each construct is translated into actionable design principles, which are then expressed through specific, observable design behaviors in real sidewalk encounters. Rather than treating trust as an abstract outcome, the framework works from trust to experience, and from experience to design action, ultimately creating a clear line of sight between what users feel and what designers build.

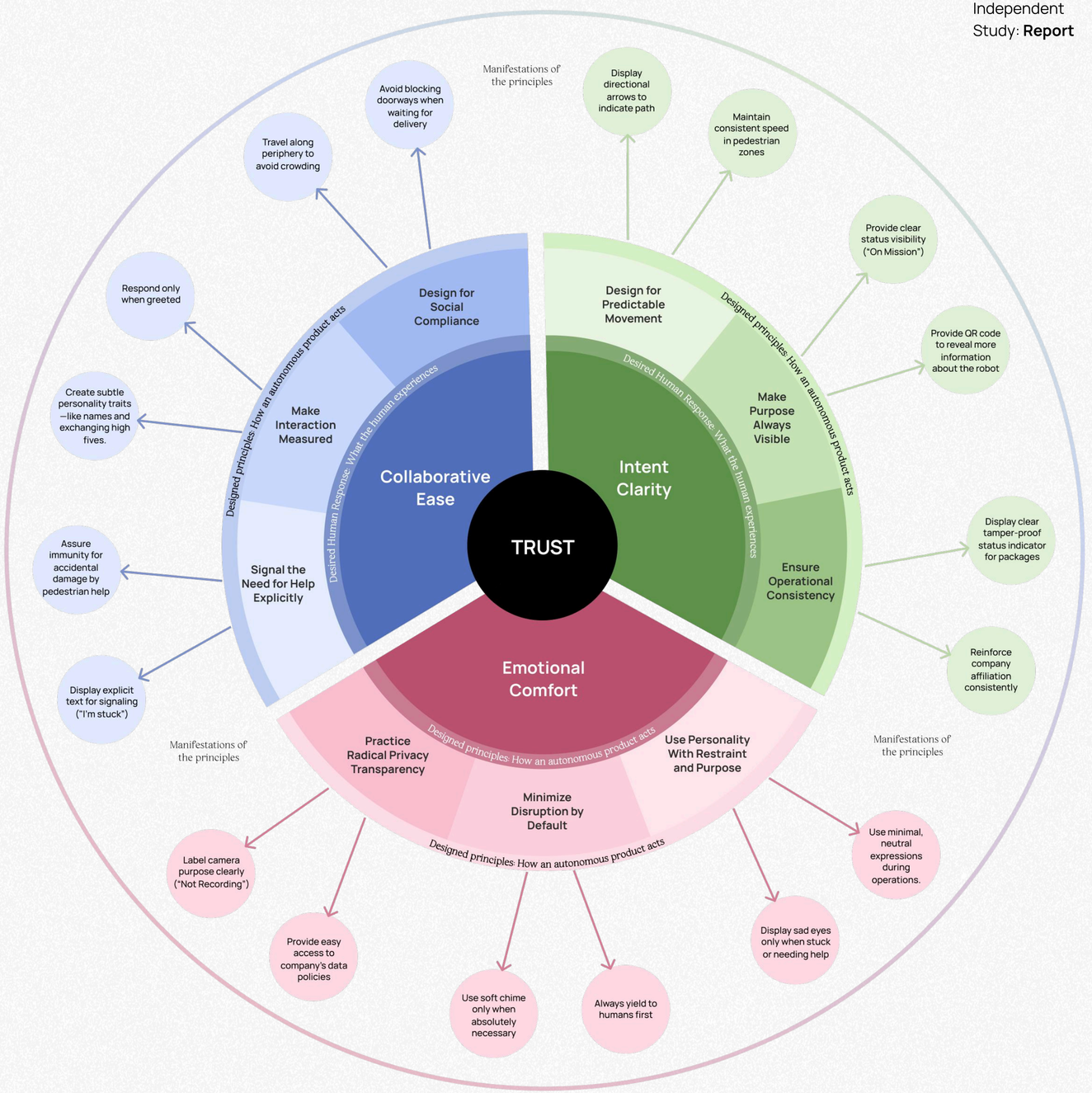
The design manifestations in the outermost layer ensures the framework is not only theoretical, but directly implementable across contexts.



Context of application: Delivery Robots

Rather than serving as a prescriptive checklist, the framework functions as a diagnostic and generative tool. It supports both evaluation of existing behaviors and exploration of new interaction strategies during early-stage design, testing, and deployment.

This framework provides a structured way of thinking about delivery-robot behavior that moves beyond basic technical performance toward community acceptance and long-term reliance. By making these relationships explicit, the framework helps teams design not just what robots do, but how they are socially experienced.



Section 1:
Collaborative Ease

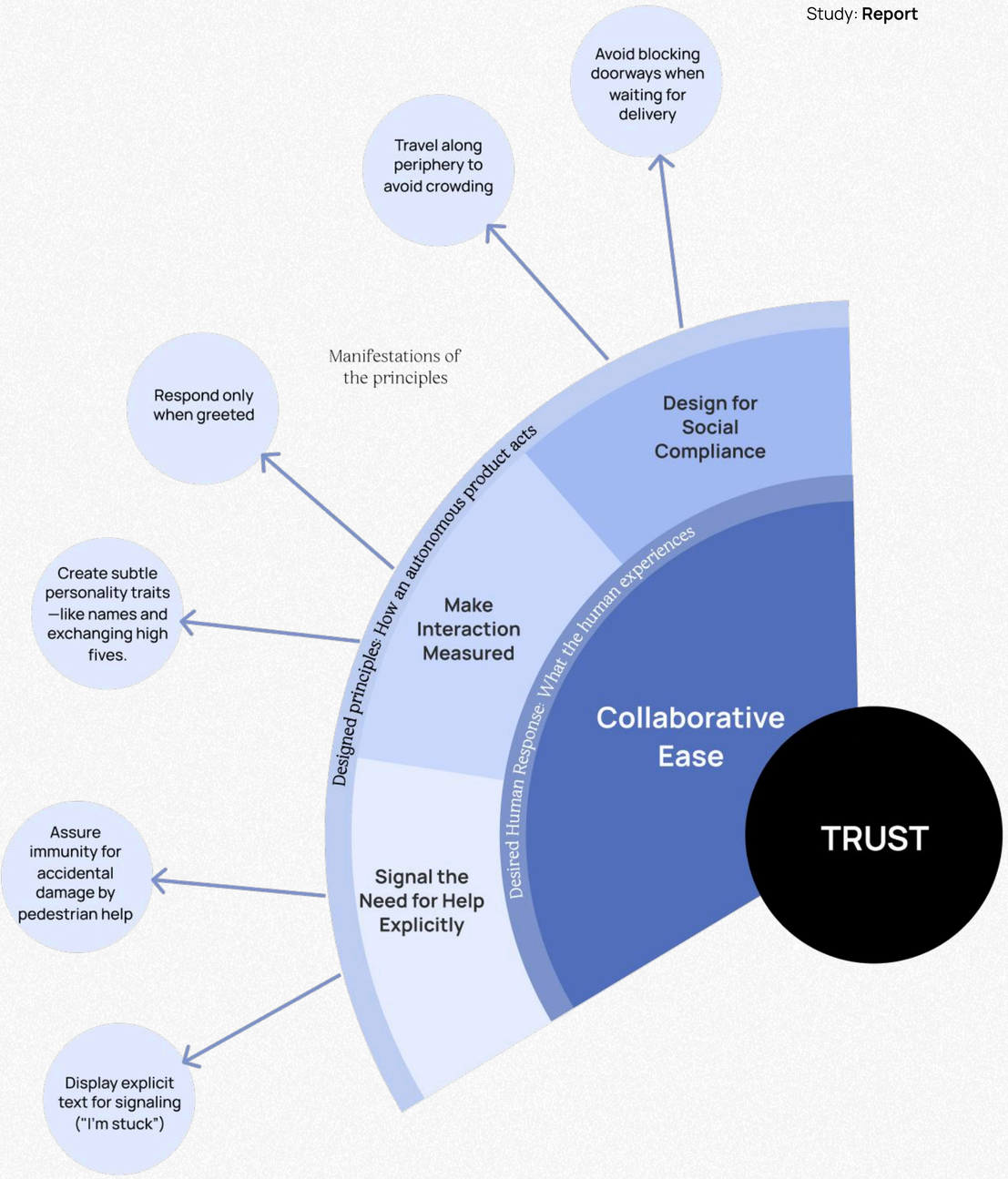
Collaborative Ease describes how effortlessly humans and robots coordinate in shared space. It reflects whether a robot reduces cognitive and physical effort, or adds friction to everyday movement.

Insights from the questionnaire:

- **People prefer robots to fade into the background of public space.**

  Participants consistently favored quiet, non-intrusive robots that behave more like infrastructure than social actors. Robots were most trusted when they occupied minimal cognitive and sensory bandwidth.

- **70%** of participants, when asked which robot most clearly communicated a need for help, chose the robot that explicitly said “Please help! I can’t move,” showing that direct distress signals are essential in failure moments.



Section 2:
Intent Clarity

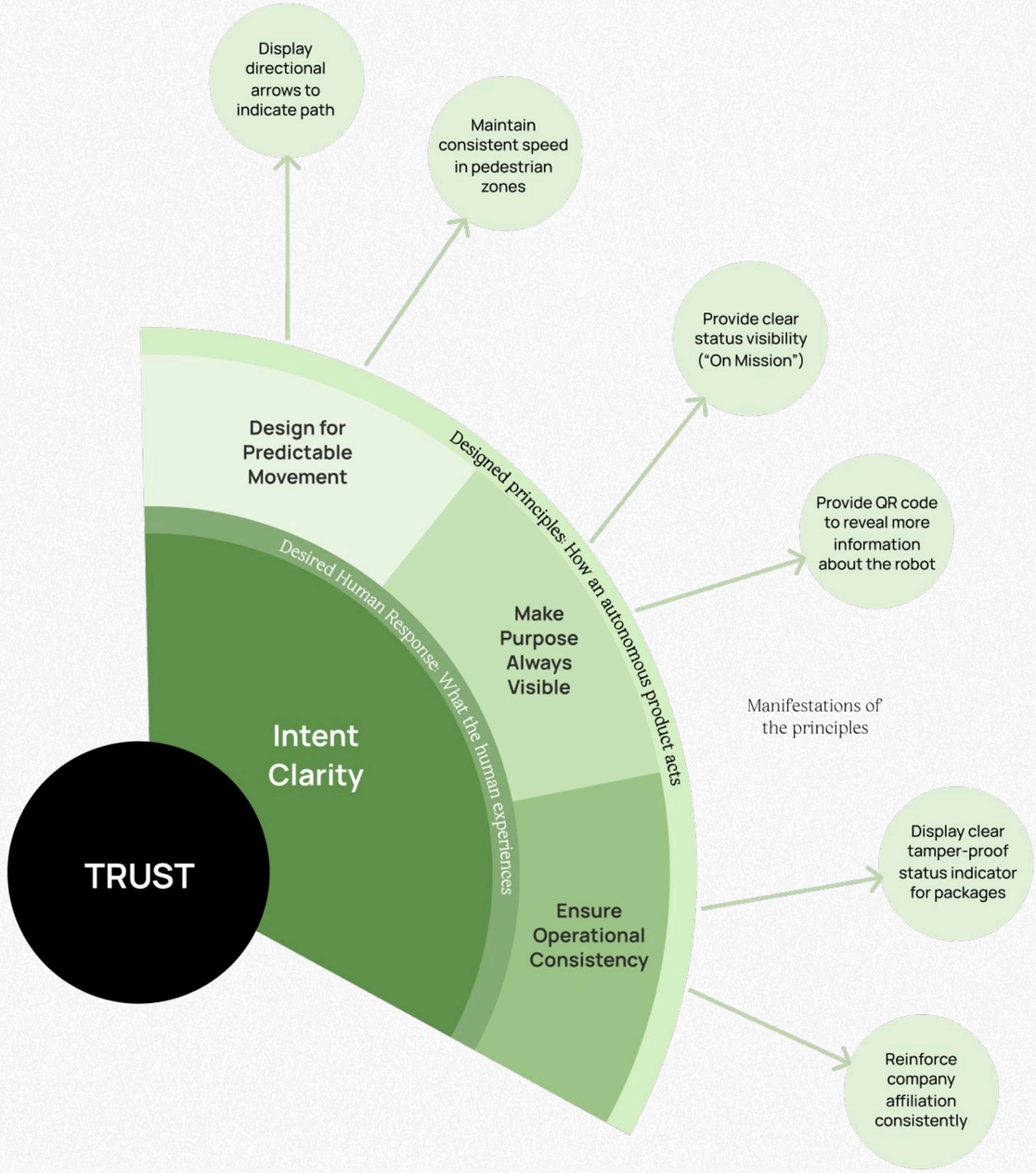
Intent Clarity addresses how transparently a robot communicates its purpose, direction, and state. Predictable movement, visible status, and operational consistency reduce uncertainty in shared environments.

Insights from the questionnaire:

- **Trust is highly sensitive to predictability and directional intent of the robot.**

  Unclear movement, blocked paths, or unexplained pauses produced the strongest discomfort. When people had to guess what the robot would do next, perceived safety dropped immediately.

- **56%** of participants, when ranking behaviors, selected “the robot clearly displaying what it’s doing” as most important—reinforcing Intent Clarity as a primary driver of comfort and cooperation.



Section 3:
Emotional Comfort

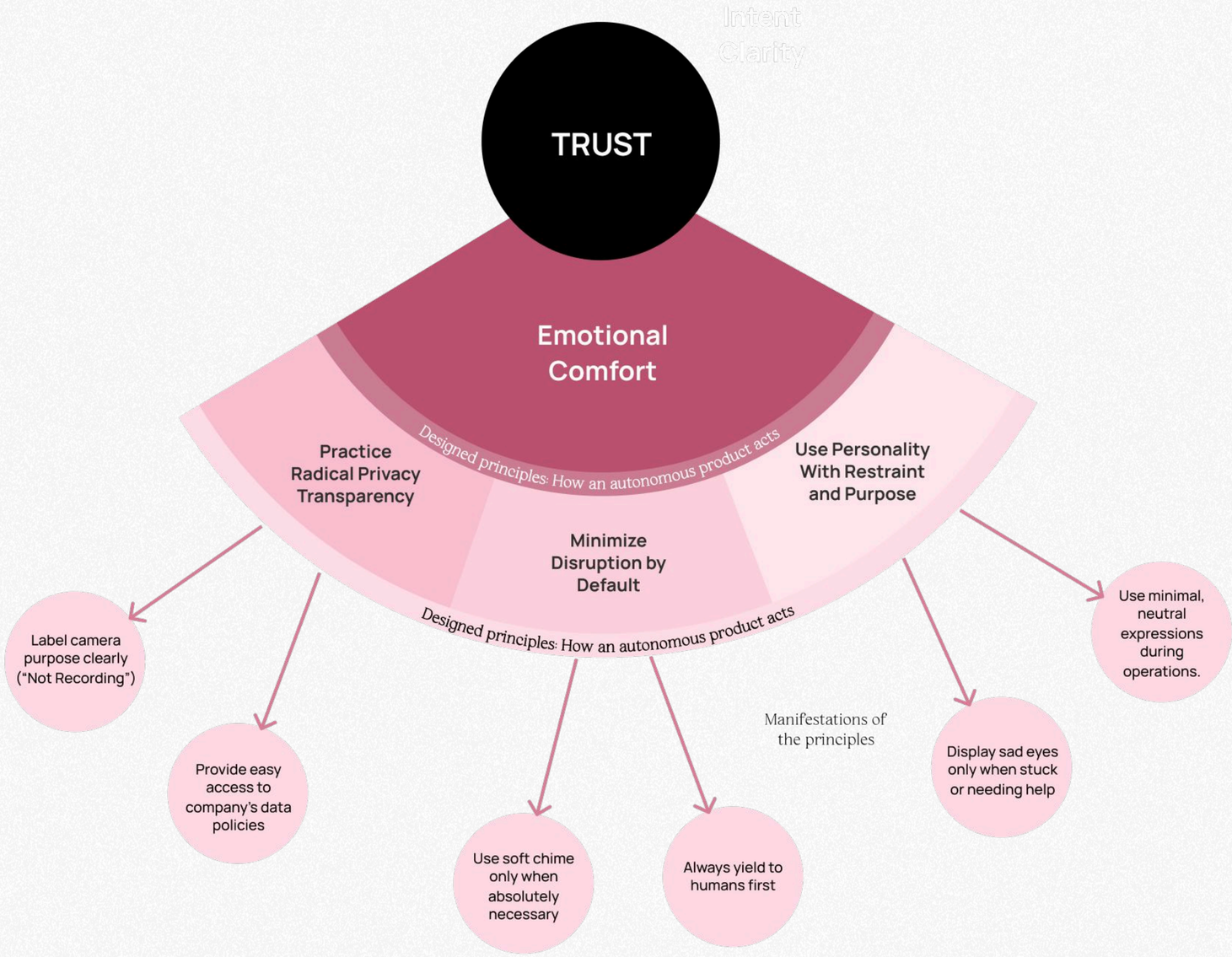
Emotional Comfort centers on how safe and at ease people feel in the presence of a robot. It emerges when robots communicate restraint, respect boundaries, and express emotion only when appropriate.

Insights from the questionnaire:

Robot's emotiveness is only valued in moments of need.

Participants consistently favored quiet, non-intrusive robots that behave more like infrastructure than social actors. While neutrality is preferred in normal operation, participants responded most strongly to robots with explicit messaging only to convey something. Emotion worked best when it was situational, not constant.

64% of participants, when asked which robot they felt most comfortable approaching, preferred one using simple, polite motion cues, suggesting that calm signaling beats expressive personality for comfort.



Using the framework in *practice*

This framework is intended for designers and engineers working on autonomous systems that operate alongside people. For shaping behaviors, UX and HRI designers can use it to design communication methods and expressive interfaces. Product teams can define behavior specifications and feature priorities to generate new ideas.

It can also support company leadership and deployment teams in making strategic decisions about where, when, and how any anthropomorphized or autonomous technology is introduced into public environments, anticipating public perception, acceptance, and long-term coexistence.

When to use the framework

The framework can be applied across multiple stages of development from early concept exploration to aligning technical behavior with human experience goals, and even during prototyping and testing to evaluate trust-relevant interaction quality. It functions both as a generative design tool for exploring new interaction strategies and as an evaluative lens for assessing whether existing robot behaviors genuinely support trust in real-world public contexts.

TL; DR

This study reframes trust in autonomous robots as a byproduct of technical intelligence, and as an outcome shaped through everyday human encounters in shared public space. It also treats trust as a recurring human–technology design challenge that is both well-established and newly manifesting in autonomous systems, shaped through everyday human experience. By examining how people interpret, work with, and respond to robot behavior on sidewalks, this work surfaces Collaborative Ease, Intent Clarity, and Emotional Comfort as core experiential conditions for trust.

The resulting framework translates these human constructs into actionable design principles and observable robot behaviors, offering designers and teams a structured way to move from abstract values toward concrete interaction decisions that can be applied beyond delivery robots, across contexts where non-human agents must coexist with people.

As autonomous systems continue to scale into public life, from delivery robots to other emerging anthropomorphized technologies, this work argues that their success will depend not only on how well they navigate environments, but on how intentionally they are designed to coexist with the people around them.

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