POSSIBILITY THEORY

A Foundation for Theoretical and Empirical Explorations of Uncertainty

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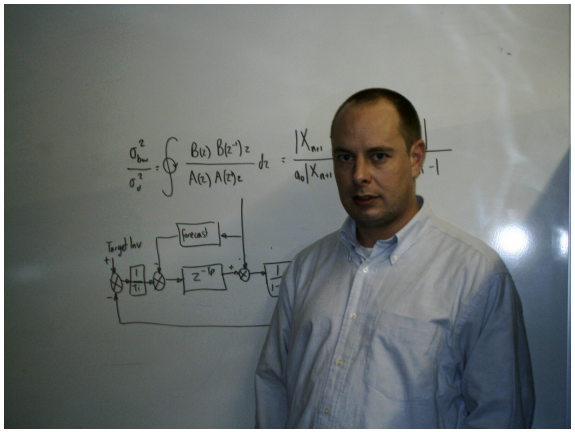
Celebrating 60 years of the Logistics Systems Dynamics Group

Cardiff University. 13th July, 2026

This presentation is based on Pil, F.K., Disney, S.M., Holmström, J., Lawson, B., Tang, C., 2024. Possibility theory: A foundation for theoretical and empirical explorations of uncertainty. *Journal of Operations Management* 70, 1182–1193.

I would also like to thank Frits Pil and Leroy White for their thoughts and feedback on quantum thinking.

LSDG and me



When you change the way you look at things, the things you look at change, Gigerenzer (1991)

- Operation and supply chain management (OSCM) research traditionally examines risk through:
  - Variability (dealing with known probability distributions)
  - Mitigation strategies (safety stocks, safety lead times, buffer capacity)
- Uncertainty research focuses on:
  - Known risks (disruptions)
  - Knowable unknowns (pandemics, extreme weather events)
  - Unknown unknowns (? as they are unknown!)
- We propose a shift from **Risk and Uncertainty** → **Possibilities**
- The possibility shift opens our minds from the inward/negative framing of "how do I cope?" to the outward/positive framing of "what new opportunities are available?"

Traditional view of uncertainty

Traditional intuition: The system has a state, we can observe it without changing it, the parts can be analysed independently, better prediction produces better control.

Focus

- Prediction
- Probabilities
- Risk mitigation
- Response strategies

Methods

- Statistics
- Optimisation
- Forecasting
- Theory testing

The key question from a traditional view of risk and uncertainty is:

How do we reduce/manage/mitigate risk and uncertainty?

The possibility lens

Core idea

Uncertainty should be viewed as unresolved states of possibility rather than merely as risk.

Possibilities may include:

- New techniques/methods/tools
- New technologies
- New practices
- Novel business models
- Re-combinations of existing capabilities
- Alternative operational designs

Key question: *What is possible (actualised), unrealised, available, constrained, feasible, or infeasible?*

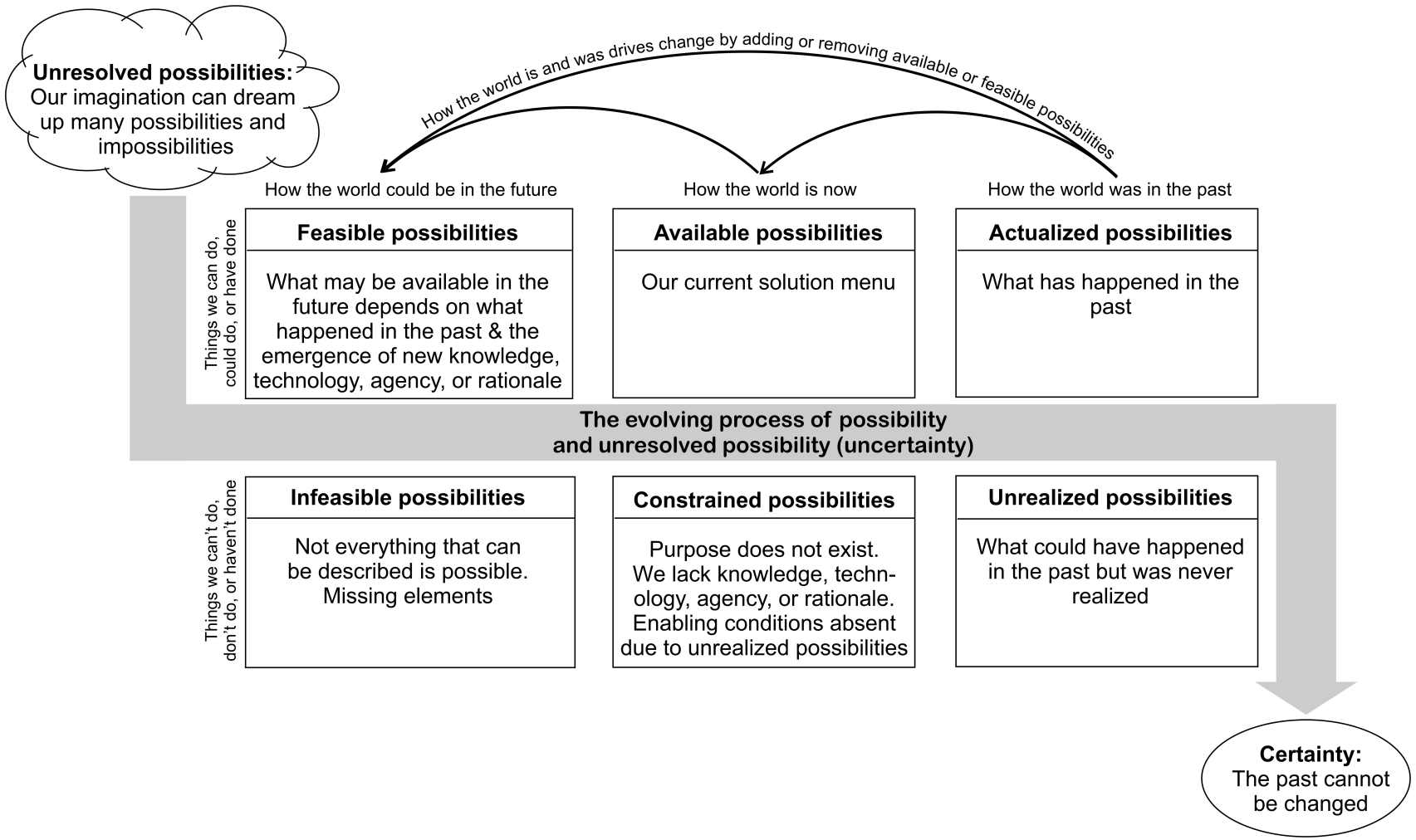
Theoretical foundations

- Possibility theory considers economic activity and operations to be part of an evolving socio-technical system that invites one to reflect on what is *possible* or *impossible*, Simon (1962, 2002); Arthur (2009).
- Socio-technical systems evolve through competition and selection, and also via purposeful cultivation. New capabilities can be designed and recombined with others, Simon (1996).
- Possibility theory considers how the world is, how it can and cannot be in the future, and how it was and could have been in the past. This *path dependence* means that future possibilities depend on the possibilities that have come before (Hintikka and Hintikka, 1989; von Wright, 1951).

Organisations operate within evolving socio-technical systems which continuously expand and constrain possibilities.

$$Past \rightarrow Present \rightarrow Future$$

The evolving nature of possibilities, Pil et al. (2024)



The superposition principle of unresolved possibilities (multiple futures are present): Unresolved states of possibility should to be left open as we explore what may be. This allows for the maximum set of possible future possibilities.

Possibilities (or elements) are a broad construct

- Novel technologies, practices, and procedures (quantum technology, blockchain).
- Re-imaging application of existing ways of doing things (gig economy).
- Deployment of technology (AI, drones).
- Management policies and practices (VMI).
- Novel ways of working (sharing economy, work from home).
- Process infrastructure (digital supply chains).
- Algorithms (forecasting methods, replenishment policies, etc.)

A possibility framework

Category	Prompt
Actualised possibilities	What are we already doing that works?
Unrealised possibilities	What could we have done before but did not?
Available possibilities	What could we do now with current authority, tools, relationships, and data?
Constrained possibilities	What seems desirable but blocked? By what?
Feasible possibilities	What might become possible if one missing element appeared?
Infeasible possibilities	What sounds attractive but is not actually possible now?

Possibilities as an evolutionary process

$$\text{Actualized} \leftrightarrow \text{Available} \leftrightarrow \text{Feasible}$$

- Path dependence restricts possibilities.
- Technological advances create possibilities.
- Time itself expands possibility space.
- Many more possibilities exist than are realised.

Definition

Uncertainty is an unresolved possibility.

From risk to possibility

Risk lens	**Possibility lens**
Mitigate uncertainty	Explore opportunity
Past and present	Past, present, future
Theory testing	Theory building + elaboration
Probabilities	Possibility spaces
Optimization	Exploration and discovery
Prediction	Understanding emergence

Research opportunities

Possibility theory advocates studying:

- Outliers. Learn from exceptional cases.
- Unexpected successes and failures. Why was Disney such a success?
- Unique contexts. Crises, pandemics, unusual industries.
- Rare events and edge cases.
- Configurations of capabilities. Necessary and sufficient conditions.

Rather than only asking *"Does X lead to Y?"*, we also ask *"What else could have happened?"*

Studying future possibilities

Two important questions:

Question 1

What missing elements currently prevent a possibility from becoming real?

Question 2

What emerging technologies or practices could make it feasible?

Examples:

- AI
- Digital manufacturing
- Autonomous systems
- Novel supply chain architectures
- ...

Possibility theory and quantum theory

Possibility theory reorients us to what we are looking for. Quantum thinking helps us embrace uncertainty in that process.

Quantum theory studies the subatomic scale. Quantum thinking can be applied to all levels.

Intuition	**Quantum framing**
Separate things act independently	Parts of a system have rich connections
Observing reveals what is there	Observing can change what is real
Things are in one state or another	A system can hold multiple potential states before observation
A process has a clear path	Multiple paths may interact before an outcome is observable

Quantum thinking helps us explore how possibilities interact

Possibilities become connected or disconnected, amplify or counter each other, remain open (unresolved), or collapse (actualised).

This moves us from thinking about determinism to reasoning based on measurement, superposition, entanglement, and interference.

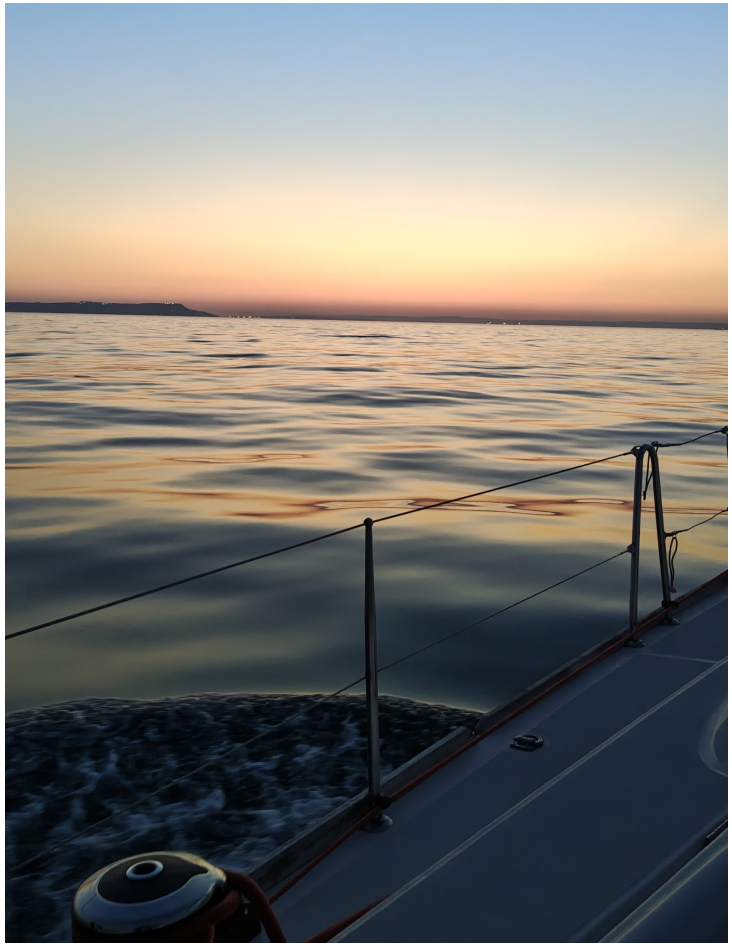
Quantum idea	**Translation**	**Possibility theory question**
Measurement	Observation changes what is observed	What do dashboards, target outcomes, reviews, audits, cause people to do?
Superposition	Multiple potential states remain open before an outcome occurs	How do we avoid prematurely locking in on a chosen future?
Entanglement	Parts of a system are connected. Modification of one part changes the whole	What key stakeholders, policies, administrative units, technologies, decision makers, are connected in ways we underappreciate?
Interference/ amplification	Some pathways interact in ways that negate each other or strengthen each other	What amplifies desirable possibilities? What suppresses them?

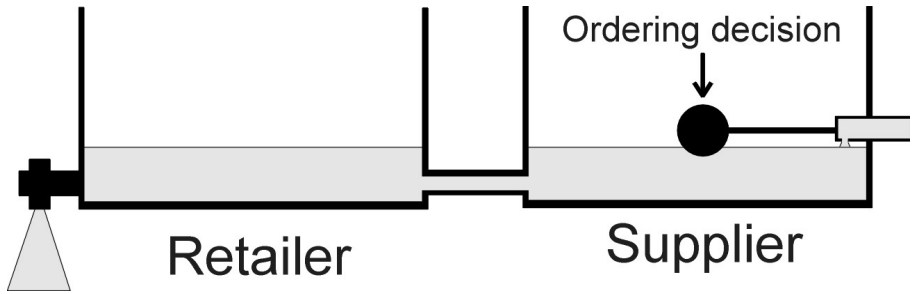
How do we delay premature lockout of future possibilities, uncover hidden relationships, and design conditions to make desired futures more likely?

A quantum possibility framework

Category	Possibility prompt	Quantum prompt
Actualised possibilities	What are we already doing that works?	What collapsed this into reality?
Unrealised possibilities	What could we have done before but did not?	What path was available but not amplified?
Available possibilities	What could we do now with current authority, tools, relationships, and data?	What states are now open?
Constrained possibilities	What seems desirable but blocked? By what?	What observation, rule, metric, or dependency is constraining the space?
Feasible possibilities	What might become possible if one missing element appeared?	What would amplify this future?
Infeasible possibilities	What sounds attractive but is not actually possible now?	Is this physically, institutionally, politically, technically, economically impossible?

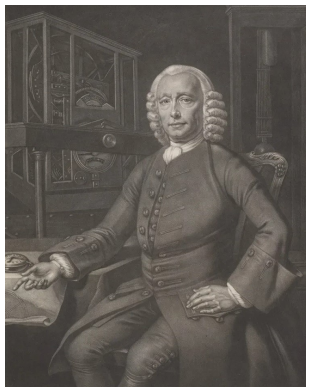
Two examples: Longitude and VMI



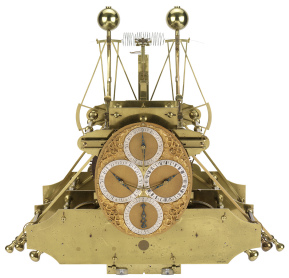


Holweg et al. (2005) provides a water-tank-based analogy for various supply chain collaboration schemes, including VMI.

Example: Determining your longitude at sea



John Harrison,
1693–1776



Harrison's first
chronograph, H1

Conventional interpretation

The longitude problem is usually presented as a problem of uncertainty reduction:

- Navigators could determine latitude by determining the highest angle to the sun (at local noon).
- Longitude remained difficult (as you need to know the current time at Greenwich).
- Better clocks solved the problem.

Key question: *How do we determine longitude accurately?*

A possibility-theoretic reframing

Instead of asking:

How was location uncertainty reduced?

we ask:

How did the space of navigation possibilities evolve?

With possibility theory, uncertainty becomes an unresolved state between what is:

- possible,
- available,
- actualised,
- impossible,
- constrained,
- unrealised.

1200: A highly constrained possibility space

Actualized possibility

- Dead reckoning

Available possibilities

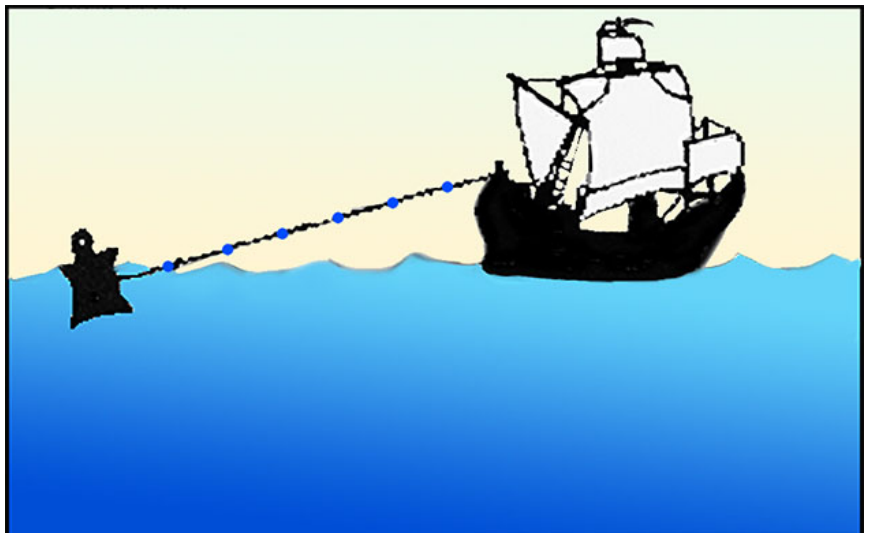
- Latitude estimation
- Coastal navigation

Unavailable possibilities

- Accurate longitude determination

Constraint

- No precise, portable timekeeping available



Counting the number of knots (47 feet and 3 inches apart) that pass in 28 seconds reveals the boat speed (in nautical miles per hour, aka knots).

Longitude was not a calculation problem. It was a possibility problem.

The possibilities available in the year 1200

- Dead reckoning ✓
- Coastal pilotage ✓
- Cross-staff ✓
- Sextants ×
- Marine chronometer ×
- Radio navigation ×
- Satellite navigation ×

Sextants can be used to determine the angle to celestial objects (the sun and stars) to determine latitude.

The vast majority of today's navigation possibilities did not yet exist in the socio-technical system.

1550: Expansion without resolution

In 1550, new enabling elements were available:

- Better charts
- Magnetic compasses
- Ocean-going ships
- Improved astronomy (Astrolabe)

Furthermore, **longitude by time** was known conceptually. However, it remained unavailable in practice.

Mariner's compass c1570

Possibility perspective

A feasible possibility may exist long before it becomes an available possibility.

The Longitude Act (1714)

Traditional interpretation:

"Government funds search for solution."

Possibility interpretation:

"The Longitude Act expanded exploration of the possibility space."

A range of potential solutions were proposed:

- Lunar distance methods
- Celestial methods
- Precision clocks...

These navigation futures were in **superposition** – lunar distance, celestial approach, precision clocks – all remained unresolved possibilities.

The key issue became: *"Which possibility will actualise?"*

John Harrison and possibility actualization

Before Harrison:

$$\text{Feasible} \rightarrow \text{Unavailable}$$

After Harrison:

$$\text{Feasible} \rightarrow \text{Available} \rightarrow \text{Actualized}$$

Chronometers transformed longitude from a theoretical possibility into an operational reality.

Why chronometers won

Longitude was not solved by a single invention. It depended upon:

- Precision engineering
- Metallurgy
- Scientific knowledge
- Maritime institutions
- Naval adoption
- Training and standards

Harrison's H4 pocket chronometer

Key insight

Possibilities emerge from the evolution of entire socio-technical systems. A configuration of elements is required.

Path dependence

Possibility theory emphasises path dependence:

The *actualized possibility* **marine chronometer** creates **global navigation** which enables **standard time zones** which helps create **radio navigation** which eventually enables **satellite navigation** whose weaknesses were overcome by **quantum navigation**.

Modern-day chart plotter on a yacht. Uses GPS to plot position over naval charts of water depths, traffic lanes, and navigational hazards etc.

Unrealized possibilities

Longitudinal act was an amplifier that increased the resources, legitimacy, and experimentation of possibilities.
Possibility theory also studies what did NOT happen. Examples:

- Lunar distance methods (only works on cloudless nights).
- Alternative astronomical systems (such as solar eclipse or the position of Saturn's moons).
- Different navigation architectures (navigation via different coloured fireworks was one suggestion).

These unrealised possibilities can be as theoretically interesting as the solutions that succeeded.

Evolution of the longitude possibility space

1200	Dead reckoning
1550	Improved navigation tools
1750	Marine chronometers emerge
1900	Longitude routine at sea
1950	Radio navigation
1975	Satellite navigation begins
2000	GPS dominant
2025	Multi-constellation GNSS
2026	Quantum navigation

Quantum navigation now provides precise positioning without satellites.

The space of possibilities continuously expands.

Implications for possibility theory

The longitude problem illustrates:

1. Possibilities evolve over time.
2. Feasible possibilities may remain unrealised.
3. Technologies emerge from socio-technical systems.
4. Actualised possibilities create new possibilities.
5. Uncertainty is often an unresolved possibility.

The longitude problem

The **traditional narrative** says:

"Longitude was solved by better clocks."

The **possibility-theoretic narrative** says:

"Accurate longitude evolved from an infeasible possibility to an available possibility through the co-evolution of technology, institutions, knowledge, and practice."

The longitude problem is not simply a story of reducing uncertainty. It is a story about how societies expand their space of possibilities.

Vendor managed inventory (VMI)

Traditional OSCM research asks:

How do we manage inventory and production in the face of demand uncertainty?

Possibility theory asks:

What are the possible, impossible, available, constrained, feasible, and actualised supply chain configurations?

VMI provides an ideal example as:

- The idea existed decades before implementation
- Technologies expanded the possibility space
- Regulations closed some possibilities
- New technologies continue to create new possibilities

Conceivable impossibilities

Examples:

- We could use Star Trek transporter to move stuff around. Inventory could be teleported à la The Fly.
- A Red Dwarf materialiser could produce stuff instantaneously.

Characteristics:

- Can be imagined
- Can be described
- No known path to implementation
- Outside the feasible possibility space

The imagination set is larger than the set of feasible possibilities.

1958. Possible but unavailable solutions

Magee (1958): Perfect replenishment

Customer specifies:

- Minimum inventory
- Maximum inventory

Supplier assumes responsibility for replenishment, using the flexibility the minimum and maximum inventory levels provides to reduce production and transportation costs.

The concept existed decades before VMI became actualised.

Interpretation

A possible, but unavailable, possibility

VMI logic was understood long before the socio-technical infrastructure existed to support it reliably.

Why was early VMI unavailable?

Missing enabling components:

- Electronic data interchange
- ERP systems
- Reliable communications
- Inventory visibility
- Trust between supply chain partners
- Data standards

Possibility theory suggests that...

A possibility may be feasible long before it becomes available.

Feasible possibilities

Disney (2001) established the mechanisms needed for VMI:

- Inventory visibility
- Demand information
- Forecasting systems
- Replenishment rules (planning and control systems)

Researchers can identify:

- Missing elements
- Enabling conditions
- Future implementation pathways

This transforms VMI from an idea into a feasible possibility.

Constrained possibilities

A solution could exist but cannot be deployed. Example reasons for non-deployment include:

- Corporate IT restrictions
- Information security policies
- Data sharing limitations
- Regulatory constraints

Example 1:

- Amazon Dash buttons were deemed to be in violation of competition/pricing laws
- Mobile apps enabled a new alternative solution

Example 2:

- Würth could not use the client's IT infrastructure
- Mobile communication technology was introduced
- The constraint was removed and a new possibility was created

2015 Amazon Dash buttons: An actualised possibility that became constrained

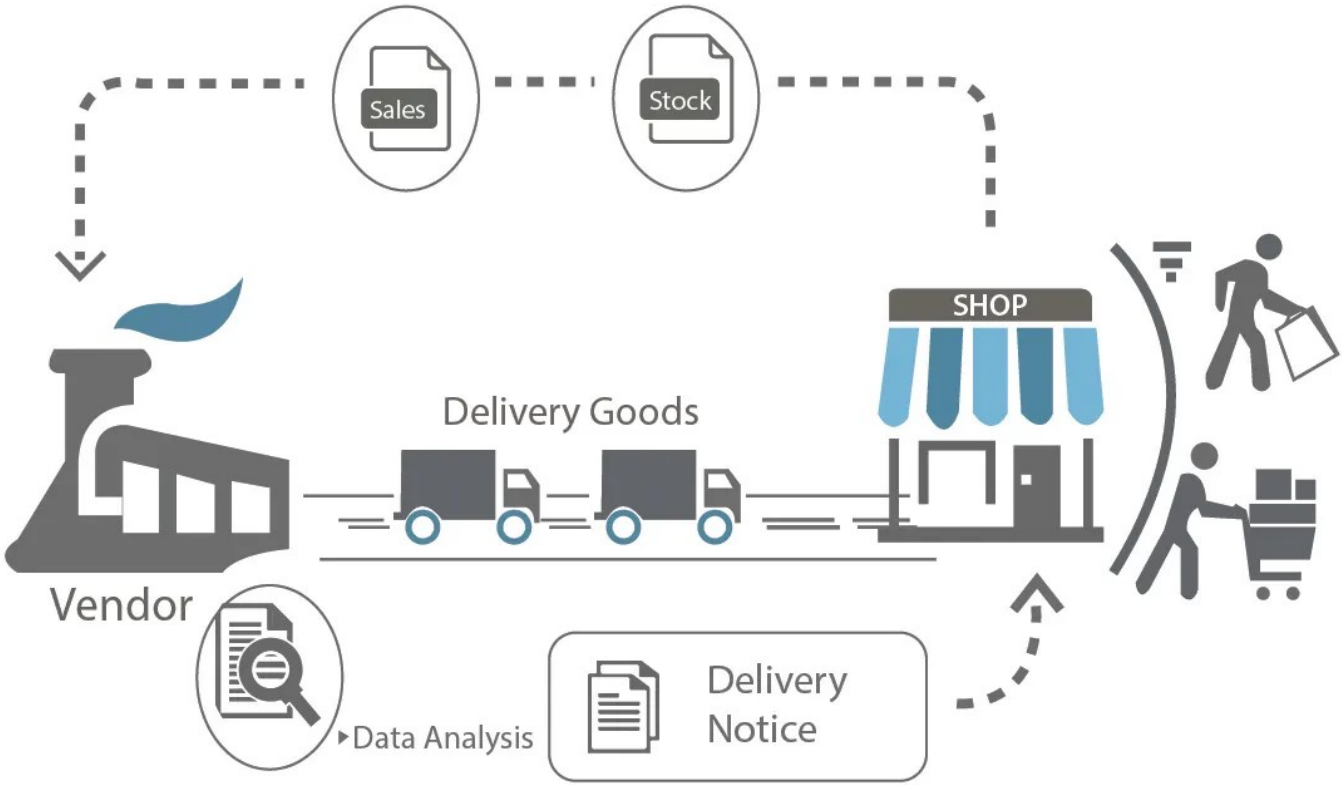
Lifecycle: *Available* → *Actualised* → *Constrained* → *Removed*

Amazon Dash button disappeared in 2019 because:

- Smartphones emerged
- Smart appliances emerged
- Alexa/Siri emerged
- Regulation changed

Key insight: Possibilities can disappear as well as emerge.

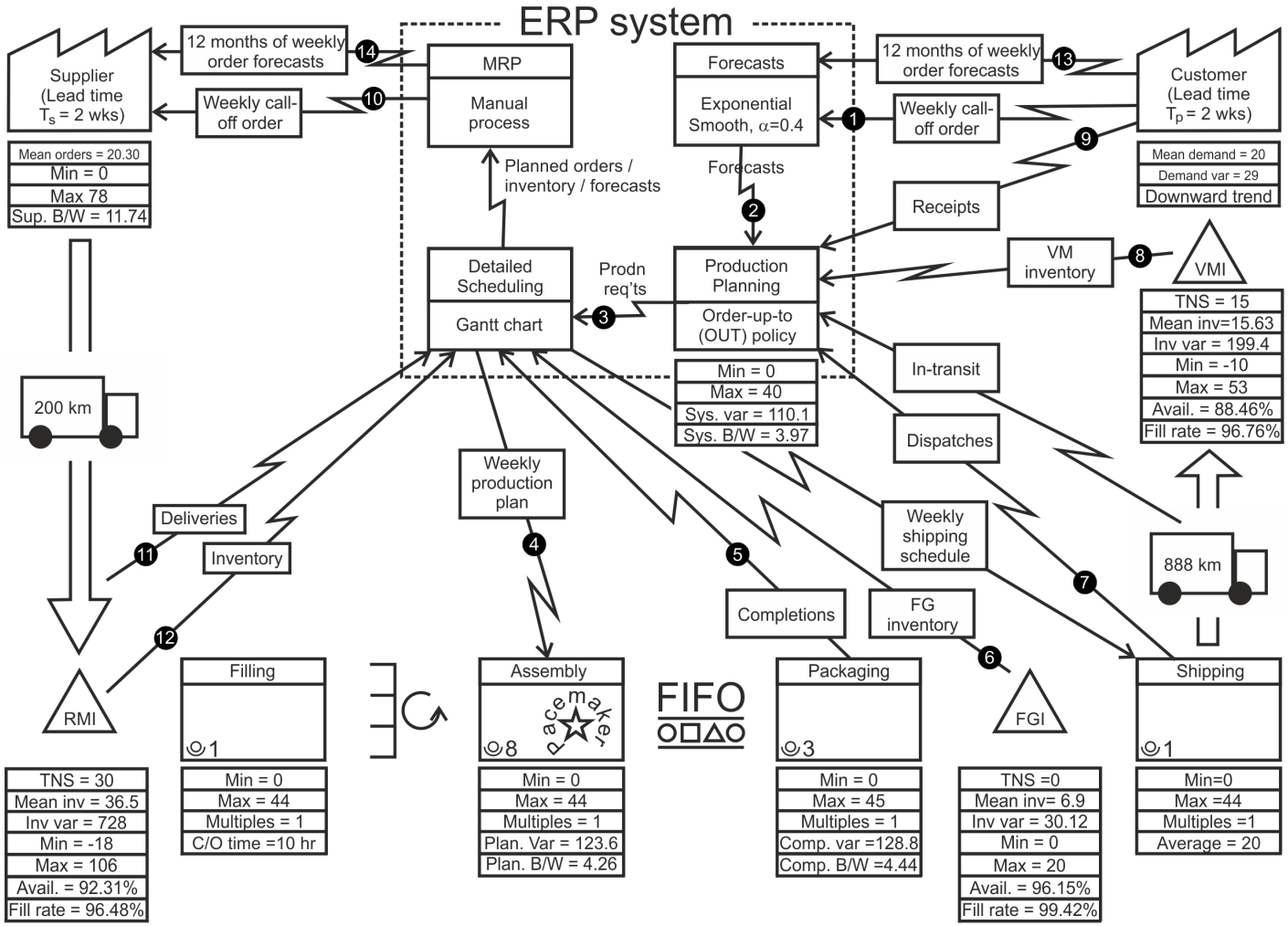
1992. Actualised VMI possibilities I: Walmart



Walmart uses satellites to make supply chains transparent, Waller et al. (1999)

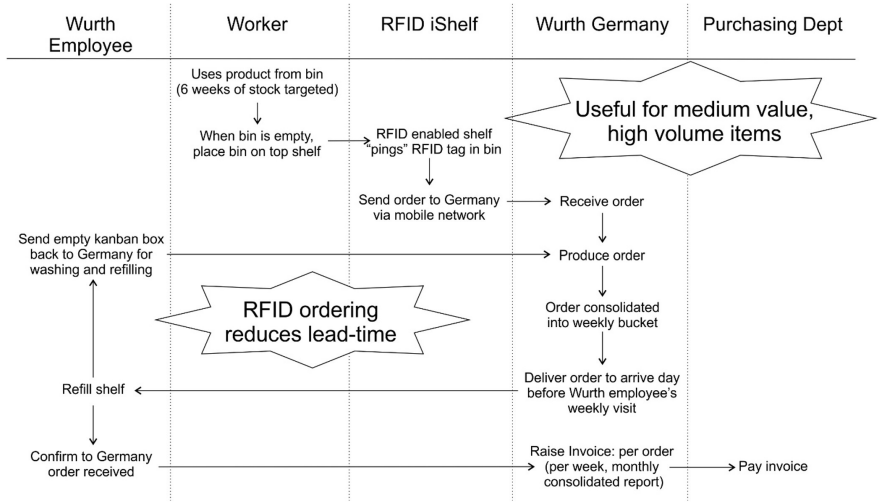
Key insight: Walmart had to wait for enabling elements (barcodes, electronic point of sales data, satellite data communication) to become economically available to effectively use VMI. Possibilities emerge as technology evolves.

2012 Actualised VMI possibilities II: Lexmark



Lexmark owned and managed toner inventory at the cartridge assembly sites, Disney et al. (2013). A global IT system (SAP) provided visibility of the supply chain (demand, inventory, deliveries, shipments, production etc.). SAP's planning book created forecasts and set production and delivery targets.

2019 Actualised VMI possibilities III: Würth, RFID-enabled VMI replenishment



RFID-enabled kanban boxes, smart shelves, and mobile data connections allow for automated VMI replenishment without interacting with customers' IT systems.

Key insight:

VMI is not a solution. VMI is a family of possibilities.

Emerging, future, VMI possibilities

New technologies introduce new components/elements:

- Additive manufacturing
- Smart materials
- Machine vision
- AI agents
- Quantum computing
- Blockchain
- ...

A possibility-theoretic research question:

How will these technologies change what VMI can become?

Why simulation matters

Traditional empirical research studies:

- Existing systems
- Historical data
- Actualised possibilities

Simulation allows us to study:

- Feasible possibilities
- Future systems
- Missing components
- Alternative configurations

Key insight:

The search therefore moves beyond *"What happened?"* to *"What could happen?"*

VMI conclusions

1. VMI is not a single solution.
2. VMI is an evolving possibility space.
3. Technologies expand and constrain possibilities.
4. Actualised solutions create new possibilities.
5. Simulation and modelling helps us study possibilities:
   - before they exist,
   - while keeping multiple futures open,
   - without disturbing the set of unresolved possibilities.

The question is not *"What is known?"*, but *"What is possible?"*

Over to you

- In small groups, pick a problem/issue/scenario to analyse through the lens of possibility theory.
- How have our possibilities changed over time? What could come in the future? What are the missing elements to enable that future? What could we have done in the past that we did not do?
- Suggested topics to study with possibility theory: a) Listening to music. b) International travel. c) Any problem you wish to study.
- Hint:

Category	**Prompt**
Actualised possibilities	What are we already doing that works?
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Infeasible possibilities	What sounds attractive but is not actually possible now?

The number of unrealised possibilities is an expanding set

In your small groups, discuss your possibilities from a quantum perspective:

- What futures are in superposition?
- What measurements or decisions might collapse a future too early?
- What actors, technologies, or systems are entangled?
- What would amplify the most desirable future?

Final thoughts on possibility theory

- Uncertainty can be viewed as **unresolved possibilities**.
- Organizations operate within evolving socio-technical systems.
- Possibilities are created and constrained over time.
- Research should seek/examine unrealised and future possibilities.
- Quantum thinking can help us understand the set of unresolved possibilities.

The conceptual shift

"How do we manage uncertainty?"

verses

"What is possible, and how does the space of possibilities evolve?"

Thank you for listening

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Evolution of book publishing possibilities

Possibility theory perspective: Publishing evolves as technologies and institutions expand the set of possibilities available to authors and readers.

Period	Dominant publishing possibility
Before 1450	Handwritten manuscripts
1450–1800	Printing press and printed books
1800–1950	Industrial publishing houses
1950–1995	Mass-market paperbacks
1995–2010	Online booksellers and print-on-demand
2010–2025	E-books and self-publishing platforms
2025+	AI-assisted publishing

Key insight: Each technological shift expanded who could publish, how books were distributed, and the range of publishing possibilities available to society.

Future possibilities for book publishing

From actualized to feasible possibilities: *Traditional publishing* → *Self publishing* → *eBooks* → *AI publishing* → *Adaptive books*

- **Actualized possibilities:** Traditional publishers, Amazon, Kindle Direct Publishing.
- **Available possibilities:** Global digital distribution and print-on-demand.
- **Emerging possibilities:** AI-assisted writing, editing, translation, and marketing.
- **Feasible future possibilities:** Personalised books that adapt content to individual readers.
- **Long-term possibilities:** Immersive, interactive, and co-created reading experiences.

Possibility lens question: *What new forms of creating, distributing, and consuming books become possible as technology and society evolve?*

Evolution of music listening possibilities

Possibility theory perspective: Technologies create, constrain, and expand the set of ways people can listen to music over time.

Period	Dominant possibility
Pre-1877	Live music only
1877–1920	Phonographs and recorded music
1920–1950	Radio broadcasting
1950–1980	Vinyl, cassettes, portable radios
1980–2000	CDs and Walkman listening
2000–2010	MP3 players and downloads
2010–2025	Streaming anywhere, anytime

Key insight: Each new technology did not simply replace the previous one; it expanded the set of available listening possibilities while making some older possibilities less relevant.

Future possibilities for music listening

Moving from available to feasible possibilities: *Streaming Platforms → AI Personalization → Generative Music → Brain – Computer Interfaces*

- **Actualized possibilities**: Spotify, Apple Music, YouTube Music.
- **Available possibilities**: AI-curated playlists and adaptive recommendations.
- **Feasible possibilities**: Music generated in real time for an individual's mood, context, or activity.
- **Long-term possibilities**: Direct neural interfaces creating personalized audio experiences.

Possibility lens question: *What new ways of experiencing music become possible as technology and society evolve?*

Evolution of international travel possibilities

Possibility theory perspective: International travel has evolved as new technologies, infrastructure, and institutions expanded the set of mobility possibilities available to individuals. Pil et al. (2024)

Period	**Dominant travel possibility**
Before 1800	Sailing ships, horses, caravans
1800–1900	Steamships and railways
1900–1950	Ocean liners and early aviation
1950–1990	Jet aircraft and package holidays
1990–2010	Budget airlines and online booking
2010–2025	Mobile travel platforms and e-visas
2025+	AI-enabled travel planning

Key insight: Each technological and institutional innovation expanded who could travel internationally, how quickly they could travel, and the destinations that became accessible.

Future possibilities for international travel

From actualized to feasible possibilities: *Steamships → Oceanliners → Aeroplanes → Jets → Budget Airlines → Autonomous & Space Travel*

- **Actualized possibilities:** Commercial aviation, budget airlines, online booking platforms.
- **Available possibilities:** Real-time itinerary management, digital passports, biometric border control.
- **Emerging possibilities:** AI travel agents that design and optimise entire journeys.
- **Feasible future possibilities:** Autonomous aircraft, advanced supersonic travel, seamless global mobility.
- **Long-term possibilities:** Commercial space tourism and immersive virtual-physical travel experiences.

Possibility lens question: *What new forms of international mobility become possible as transportation, digital technologies, and institutions evolve?*