PS-02 Group size thresholds: Dunbar's layers and the span of control

The Evolutionary Architecture of Sociality: Dunbar's Layers and Cognitive Bandwidth

The premise that human social structures are anchored in neuroanatomical constraints was systematically formulated by Robin I. M. Dunbar (1992, 1993, 2010) through the Social Brain Hypothesis[1]. Analyzing anthropoid primates, Dunbar identified an allometric relationship: the ratio of neocortical volume to the remainder of the brain correlates with mean social group size[1]. Extrapolating this cross-species regression to the human neocortical ratio (approximately 4.1:1) produced a predicted mean group capacity of 147.8 individuals, conventionally cited as the Dunbar Number of 150[1]. Rather than representing an isolated ceiling, this scalar point functions as an anchor within a nested hierarchy of social group sizes characterized by an approximate scaling ratio of 3.0 (empirically bounded between 2.8 and 3.4)[6].

Social Tier Layer	Mean Population	Interaction Frequency	Primary Psychological and Operative Function
Support Clique	4–5	Daily / Continuous	Intimate mutual aid, acute crisis response, emotional shelter[6]
Sympathy Group	12–15	Weekly	Tactical task allocation, high trust, mutual loss grief[6]
Affinity Band	45–50	Multi-weekly	Co-residential foraging camp, seasonal cooperative labor[6]
Active Network	150	Monthly / Seasonal	Direct reputational tracking, self-policing social order[1]

Mega-Band / Cohort	500	Annual / Periodic	Regional marital exchange, resource hedging, regional assemblies[6]
Ethnolinguistic Tribe	1,500	Rare / Plenary	Shared dialect, unified ritual cosmology, defensive mobilization[6]

The statistical regularity of these tiers across historical and non-industrial populations is well documented. Marcus J. Hamilton et al. (2007) examined census data from 1,121 hunter-gatherer societies encompassing 339 distinct ethnolinguistic groups across five continents[9]. Their analysis confirmed a fractal hierarchy with mean group clusters at 3.8, 14.8, 52.4, 166.8, and 1,518.4 individuals, matching a mean branching ratio of 3.14[6]. Similarly, Russell Hill and Robin Dunbar (2003) analyzed contemporary non-commercial postal greeting networks, identifying an average network size of 153.5 individuals divided into structurally distinct tiers[1].

Methodological Critique and the Lindenfors Deconstruction

The empirical and mathematical foundation of Dunbar's extrapolations was challenged by Patrik Lindenfors, Andreas Wartel, and Johan Lind (2021) in *Biology Letters*[1]. Lindenfors and colleagues re-evaluated primate neuroanatomical datasets using modern comparative phylogenetic approaches, specifically Bayesian phylogenetic mixed models and generalized least-squares (GLS) regressions[1]. Their Bayesian regressions estimated an average human group size between 69.2 and 108.6, yet with a 95% confidence interval ranging from 3.8 to 520.0 individuals[4]. The GLS model yielded point estimates between 16.4 and 42.0, with an associated 95% confidence interval spanning 2.1 to 336.3 individuals[4].

Lindenfors et al. demonstrated that brain tissue evolution is subject to diverse selective pressures, including dietary strategy, metabolic limitations, and predatory evasion, making the neocortex ratio an incomplete proxy for social complexity[4]. Primate socio-ecology shows that group size is heavily constrained by food availability and predator density rather than brain volume alone[4]. Consequently, extracting a single human cognitive limit from primate allometry introduces substantial statistical uncertainty[4].

Dunbar defended the hypothesis by noting that Lindenfors et al. combined ecologically divergent primate clades and failed to account for behavioral time-budgets, specifically the temporal limits on social grooming and verbal conversation[13]. For institutional analysis, Dunbar's layers remain valuable not as rigid neurological ceilings, but as empirical stress points where interpersonal familiarity degrades and formal organizational structures become necessary[5].

Egalitarian Bands and Reverse Dominance Hierarchies

In small-scale human societies ranging from 15 to 50 individuals, collective governance relies

on consensus, informal sanctioning, and what Christopher Boehm (1999) designated in *Hierarchy in the Forest* as a "reverse dominance hierarchy"[15]. Rather than permitting aggressive or charismatic individuals to assert dominance, subordinates form an intentional coalition to suppress self-aggrandizing behavior[15]. This equilibrium is preserved through an escalation of social sanctions: intentional ridicule, public criticism, social ostracism, group desertion, and targeted execution[15].

Analytical Dimension	Empirical Reality
What the Group Said It Did	The Ju/'hoansi (!Kung San) and Hadza maintain that all members are equal, autonomous actors, and that authority rests in no single individual[16]. Meat belongs to the maker of the arrow, and arrogant boasts are actively mocked to maintain group parity[16].
What the Record Shows It Did	Group equality was sustained through pervasive social policing, high conformity pressures, and lethal force[16]. Richard B. Lee (1979) established that the homicide rate among the Dobe Ju/'hoansi between 1920 and 1955 was 29.3 per 100,000 annually—higher than most industrialized cities—with multiple capital executions of disruptive individuals carried out by communal agreement[20].
What Modern Scholarship Infers	Boehm (1999) and Carel van Schaik argue that band egalitarianism is not an absence of hierarchy, but an active, energy-intensive dominance hierarchy turned upside down[15]. Subordinates enforce equality through the constant threat of collective physical force[16].

Rung	Population Range	Operational Status	Structural Outcome and Failure Mechanics

Household	4 to 10	Worked	High genetic relatedness suppresses formal power struggles during daily foraging[17].
Hamlet or Band	30 to 50	Worked	Core ecological home of reverse dominance; transparent behavior allows coalitional leveling without formal courts[15].
Village	150 to 500	Operated with friction	Multi-lineage competition emerges; gossip ceases to enforce complete transparency; factionalization begins[16].
Parish or District	1,500 to 5,000	Failed	Cross-camp reputations cannot be tracked directly; requires segmentary lineage treaties or formal chiefly adjudication[17].
Town or Watershed	15,000 to 50,000	Failed	Anonymity shelters defectors; informal shaming loses regulatory force; centralized coercion emerges[17].
Region or	0.5 to 5 million	Never tried	Pure face-to-face

Bioregion			leveling cannot function across regional populations.
Nation or Continent	50 to 500 million	Never tried	Institutional and legal complexity entirely replaces relational enforcement.
Planet	8 billion	Never tried	Complete absence of common relational mechanisms.

Capture Test: Egalitarian Band Governance

An individual exhibiting dark-triad traits (narcissism, Machiavellianism, psychopathy) captures an egalitarian band by exploiting the lag between early behavioral deviance and the mobilization of a lethal coalition[15]. The aspiring autocrat builds physical intimidation, hoards rare resources, fabricates supernatural threats, and plays distinct kinship lines against one another to disrupt coalitional unity[16].

A documented historical case occurred in the Dobe area of the Kalahari Desert during the late 1960s, recorded by Richard B. Lee (1979)[20]. A hunter named Twi terrorized several camps, repeatedly asserting dominance, assaulting rivals, and murdering two individuals[20]. When he threatened a third victim, the camp formed a cross-kinship coalition[20].

To prevent ongoing blood feuds, Twi's own extended family consented to the collective verdict; hunters ambushed Twi around an evening campfire and shot him with poison arrows, terminating the autocrat through coordinated execution[20]. The structural defense against band capture relies on the universal possession of lethal weapons (such as poisoned hunting tools) that negate individual physical dominance, combined with total domestic transparency that prevents covert factional organization[16].

Communitarian Limits: Hutterite Colony Fissions and Kinship Pressures

The most documented empirical test of Dunbar's 150-person boundary in sedentary agrarian settings is the communal lifestyle of the Hutterian Brethren[4]. Tracing their origin to the Tyrolean Anabaptist movement under Jakob Hutter in 1528, the Hutterites maintain complete communal ownership of property (*Gütergemeinschaft*)[24]. Across five centuries in Moravia, Slovakia, Russia, and North America, Hutterite settlements have adhered to an institutional principle: when a colony's population approaches 150 individuals, it must split (*fission*) into two daughter

colonies[23].

John A. Hostetler (1974) and Karl Peter (1987) documented the operational realities of this boundary[23]. In a colony below 100 members, governance remains largely informal, face-to-face, and self-correcting[23]. The minister (*Diener des Wortes*) and colony council oversee labor distribution and moral discipline through direct suasion, collective meals, and daily communal contact[23].

As a colony expands toward 150 individuals, the structural dynamics change[23]. Paternal lineages (*Sippen*) consolidate into distinct political blocs[23]. Gossip ceases to align communal behavior and instead hardens into factional rivalry[23]. Kinship groups begin competing for machinery assignments, kitchen authority, and comfortable quarters, making informal consensus unworkable[23].

The Hutterites manage this friction through institutionalized budding[23]:

1. The mother colony uses pooled savings to purchase an additional agricultural tract and build a complete second settlement (housing, dining hall, barns) over several years[23].
2. When the infrastructure is prepared, the colony council divides the entire community into two demographically balanced cohorts, equalizing occupational skills, age profiles, and extended family lines[24].
3. The preacher places two slips of paper into a hat, and lots (*das Los*) are drawn in a religious assembly to decide which group remains at the established colony and which departs for the new site[24].

Because neither faction knows which half will move, both cohorts ensure that land, livestock, and equipment are divided equitably, preserving communal peace through institutionalized uncertainty[24].

Analytical Dimension	Empirical Reality
What the Group Said It Did	Hutterites explain the 150-person fission as an act of religious discipleship, maintaining spiritual humility and preventing personal pride or unchristian bureaucracy from undermining mutual love[23].
What the Record Shows It Did	Fissioning is a structural necessity to prevent factional fragmentation and physical conflict over resources[23]. Settlements that delay splitting beyond 160 members consistently experience acute governance breakdown, economic non-compliance, and severe intra-family disputes[23].

What Modern Scholarship Infers	Sociologists and evolutionary theorists view 150 as the upper cognitive limit for non-coercive communal property regimes[5]. Beyond this threshold, the number of pairwise social combinations ($N(N-1)/2 = 150 \times 149/2 =$) exceeds the capacity of unwritten social tracking, requiring either formalized judicial institutions or demographic fission[1].

Rung	Population Range	Operational Status	Structural Outcome and Failure Mechanics
Household	4 to 10	Worked	Integrated into the communal apartment block; individual autonomy is subsumed within the broader settlement[23].
Hamlet or Band	30 to 50	Worked	Pioneer phase of a newly founded daughter colony; operationally viable but requires intensive manual labor[23].
Village	150 to 500	Failed above 150	Functional equilibrium between 60 and 130 members; structural breakdown and fission occur between 130 and 160[23].

Parish or District	1,500 to 5,000	Never tried communally	Abandoned entirely at this scale; Hutterites organize as a loose conference of autonomous local colonies[23].
Town or Watershed	15,000 to 50,000	Never tried	Incompatible with direct property sharing.
Region or Bioregion	0.5 to 5 million	Never tried	Regional organization is confined to ecclesiastical leadership conferences.
Nation or Continent	50 to 500 million	Never tried	Complete absence of legal-communal integration.
Planet	8 billion	Never tried	Ideologically incompatible with universalist governance.

Counterarguments to the Dunbar Interpretation

Simon M. Evans (2012) and Donald B. Kraybill argue that the Hutterite split is driven primarily by agrarian microeconomics rather than cognitive ceilings[23]. In the modern Great Plains, an industrialized farming operation typically requires 3,000 to 5,000 acres to remain financially solvent[23]. That enterprise provides full employment for approximately 20 to 30 adult males[23]. When a colony population crosses 150 members, the pool of working adults doubles, creating disguised unemployment among young men[23]. Splitting the colony is an economic strategy to acquire additional productive land, maximize farm machinery utilization, and ensure full adult labor allocation[23].

Capture Test: Hutterite Communal Governance

An individual exhibiting dark-triad traits takes over a colony by capturing the senior ministerial office (*Diener des Wortes*), centralizing corporate finances, dominating legal deeds, marginalizing junior elders, and invoking the theological norm of complete subjection

(*Gelassenheit*) to silence internal critics[24].

This vulnerability manifested during the Schmiedeleut schism of 1992[25]. Elder Jacob Kleinsasser of the Crystal Spring Colony in Manitoba concentrated administrative authority over external investments, church funds, and patent holdings[25]. When members of the Lakeside Colony challenged his unilateral control of financial resources, Kleinsasser used secular Canadian courts to pursue expulsion orders against the dissenters (*Lakeside Colony v. Hofer*, 1992)[24]. In response, a majority of Schmiedeleut ministers convened in 1992 and voted 95 to 75 to depose Kleinsasser from the eldership[29].

Kleinsasser rejected the council's verdict, retaining the loyalty of his home colony and allied progressive communities (Group 1 / "Oilers") while forcing a permanent, acrimonious schism with the traditionalist majority (Group 2 / "Gibbs" / Committee Hutterites)[29]. The historical defenses that resisted complete capture included the independent economic assets of outlying colonies, the council's ability to mobilize a secret ballot against the autocrat, and the long-standing tradition of ministerial sortition[28].

Lethal Coordination: Military Echelons and Hierarchical Scaling Across Deep Time

Military unit organizations across independent civilizations show remarkable structural convergence, organizing fighting forces into tactical subunits sized according to Dunbar's layers and the administrative span of control[4].

Military Era and Entity	Foundational Team	Primary Tactical Unit	Intermediate Maneuver Unit	Autonomous Operational Force
Imperial Rome (Augustan) [cite: 33]	*Contubernium* (8 men)[33]	*Centuria* (80 legionaries)[33]	*Cohors* (480 men)[33]	*Legio* (~4,800–5,280 combatants)[33]
Imperial China (Ming Dynasty)	*Wu* (5 soldiers)	*Dui* (50 soldiers)	*Shao* (100) / *Ying* (500)	*Zhen* (~3,000–5,000 troops)
Mongol Empire (Genghis Khan)	*Arban* (10 warriors)	*Jagun* (100 warriors)	*Mingghan* (1,000 warriors)	*Tumen* (10,000 warriors)
Modern Armed Forces	Fireteam (4 soldiers)	Squad (9–12) / Company	Battalion (500–800)	Brigade (~3,000–5,000

(NATO)		(100–150)		troops)[6]

In the early Imperial Roman army established under Augustus (27 BC–14 AD), the *contubernium* of eight men functioned as the fundamental support clique[6]:

- Soldiers shared a leather tent, mess kit, and pack mule, building intense horizontal mutual reliance[33].
- Ten *contubernia* formed the *centuria* of 80 legionaries, commanded by a centurion assisted by an *optio*[33]. The century aligned with Dunbar's active relational boundary; the centurion maintained direct personal knowledge of every legionary's physical capabilities and courage under fire[33].
- Six centuries constituted the *cohors* of 480 men, mirroring Dunbar's 500-person mega-band, which functioned as the base tactical maneuver element capable of independent redeployment without direct intervention by the legionary legate[6].
- Ten cohorts constituted the *legio* (roughly 5,000 men), matching the upper boundary of an ethnolinguistic tribal coalition, forming a self-contained operational combined-arms formation[6].

The physical constraints of tactical communication explain this consistency[37]. In the chaos of combat, human vocal commands carry effectively across roughly 50 to 100 meters to direct at most 50 to 100 soldiers; optical signals (banners, legionary signa) extend coordination to approximately 500 troops[33]. Beyond 500 soldiers, immediate real-time coordination fails, necessitating standardized operational doctrine, delegated officer chains, and written or courier-borne field dispatches[33].

Analytical Dimension	Empirical Reality
What the Group Said It Did	Military organizations attribute operational performance to absolute top-down obedience, oaths of allegiance, and ideological dedication to the state or commander[33].
What the Record Shows It Did	Operational survival depends heavily on primary group cohesion within small units[33]. S.L.A. Marshall (1947) in *Men Against Fire* and Edward Shils and Morris Janowitz (1948) in their study of the Wehrmacht demonstrated that soldiers fight primarily to maintain the respect of comrades in their immediate fireteam or squad, with ideological commitment serving a

	secondary role.
What Modern Scholarship Infers	Military architectures navigate an inherent tension: cultivating horizontal relational bonds (in units of 8, 40, and 150) to prevent panic, while enforcing a vertical span of control (3 to 6 reports) to coordinate maneuvers across thousands of troops[6].

Rung	Population Range	Operational Status	Structural Outcome and Failure Mechanics
Household	4 to 10	Worked	The *contubernium* (8 men); shared domestic labor, field cooking, and survival mutualism[33].
Hamlet or Band	30 to 50	Worked	The platoon or Roman cavalry *turma* (30 troopers); optimal for reconnaissance and patrol missions[7].
Village	150 to 500	Worked	The Roman *centuria* and *cohors*; primary tactical units for collective line defense[33].
Parish or District	1,500 to 5,000	Worked	The Roman *legio* or modern brigade; independent combined-arms operational capacity[33].

Town or Watershed	15,000 to 50,000	Worked	Consular field army; tactical mobility requires delegated staff corps and mounted courier systems.
Region or Bioregion	0.5 to 5 million	Operated with friction	Multi-legion theater armies; subject to courier transit delays, operational blindness, and logistical vulnerabilities.
Nation or Continent	50 to 500 million	Failed historically	Prone to praetorian coups, military warlordism, and strategic command loss.
Planet	8 billion	Never achieved	Global military integration has never been realized.

Capture Test: Centurial/Military Hierarchy

The primary attack vector within military command hierarchies is praetorianism and warlordism (*caudillismo*)[33]. When troops' personal loyalties shift from the abstract civic order to an individual charismatic general—typically because that general directly secures their bonuses, equipment, and post-service land grants—the internal hierarchy can be redirected against the civilian state[33].

A classic historical case occurred in 49 BC, when Gaius Julius Caesar crossed the Rubicon with a single legion, the *Legio XIII Gemina* (roughly 5,000 men). The legionaries obeyed Caesar's personal command over the Roman Senate's legal directives because their economic security, social prestige, and battlefield survival had been tied directly to Caesar during nine years of Gallic campaigns. Similarly, in 31 AD, Lucius Aelius Sejanus concentrated the nine cohorts of the Praetorian Guard (~4,500 troops) into a single fortified barracks outside Rome (*Castra Praetoria*), using command of this force to eliminate imperial rivals and isolate Emperor Tiberius on Capri.

Historical defenses against such takeovers include strictly limited operational command

tenures, separating logistical and payroll provisioning from field generals, rotating military units across diverse provinces, and requiring civic oaths to constitutional laws rather than individual military leaders.

The Administrative Span of Control and Hierarchical Control Loss

While Dunbar's research evaluated horizontal peer networks, administrative science analyzes the vertical command of subordinates[4]. The foundational mathematical framework for the "span of control"—the number of direct subordinates an administrator can effectively oversee—was established by Vytautas Andrius Graicunas (1933) in *Relationship in Organization*[38].

Graicunas demonstrated that while the number of subordinates grows arithmetically ($n = 1, 2, 3, \dots$), the number of interpersonal interactions requiring supervisory attention increases exponentially[38]. Graicunas categorized these interactions into three distinct types[38]:

- Direct Single Relationships: Superior to subordinate (n).
- Direct Group Relationships: Superior to permutations of subordinates ($n(2^{n-1} - 1)$).
- Cross Relationships: Subordinate to subordinate ($n(n - 1)$).

The total number of administrative relationships (r) demanding managerial oversight is governed by:

$$r = n\left(2^{n-1} + n - 1\right)$$

Direct Subordinates (nnn)	Direct Single Relations	Direct Group Relations	Cross Relations	Total Relationships (rrr)
1	1	0	0	1^{38}
2	2	2	2	6^{38}
3	3	9	6	18^{38}
4	4	28	12	44^{38}
5	5	75	20	100^{38}

6	6	186	30	222[38]
7	7	441	42	490[38]
8	8	1,016	56	1,080[38]
9	9	2,295	72	2,376[38]
10	10	5,110	90	5,210[38]

When an administrator oversees four subordinates, the relational load stands at 44 interactions[38]. Expanding to eight subordinates pushes the load past 1,000 interactions; at twelve, it exceeds 24,000[38]. Lyndall Urwick (1937, 1956) formalized this into an administrative principle: no executive should supervise more than five or six direct subordinates whose work is interlocked[38]. Where tasks are simple, repetitive, and uncoupled, the span can expand (such as 20 to 30 workers per foreman); where responsibilities are complex, strategic, and interdependent, the span must contract to 3 to 5[38].

Williamson's Hierarchical Control Loss

Restricting the span of control requires adding vertical tiers, which introduces systemic communication failure[43]. Oliver E. Williamson (1967) formalized this trade-off in *Hierarchical Control and Optimum Firm Size*[44]. Williamson proved that large organizations suffer cumulative "control loss" across vertical strata[46].

If each level of a hierarchy transmits instructions and observational feedback with an operational efficiency parameter α (where $0 < \alpha < 1$, reflecting cognitive screening errors, unaligned incentives, and deliberate omissions), the fidelity of authority across m hierarchical tiers degrades exponentially:

$$\text{Effective Control} = \alpha^{m-1}$$

Assuming a transmission efficiency of $\alpha = 0.90$ (a modest 10% distortion rate per tier), a policy directive traveling across five organizational levels retains only $0.90^{5-1} = 0.90^4 \approx 0.656$ (65.6%) of its original content and intent. Across eight tiers, fidelity drops below 48%.

Subordinates filter unfavorable news and inflate performance metrics when reporting upward, while central directives become vague as they filter downward[45]. Consequently, expanding group scale through tall bureaucratic hierarchies inevitably leads to executive operational blindness and administrative sclerosis[45].

Herbert Simon's Critique

Herbert A. Simon (1946, 1947) deconstructed classical span-of-control doctrine in *Administrative Behavior*, characterizing it as an unscientific administrative proverb[43]. Simon highlighted an inescapable structural paradox:

- Administrative efficiency is said to increase when the span of control is restricted to a small number of subordinates (3 to 6)[38].
- Administrative efficiency is also said to increase when the number of administrative levels is minimized to avoid communication distortion[43].

An organization cannot obey both principles simultaneously[43]. Restricting the span of control inevitably multiplies vertical tiers, worsening Williamson's control loss and slowing decision cycles[43]. Conversely, flattening the hierarchy widens the span of control, overwhelming managers and creating severe bottlenecks[43].

Simon argued that optimal span of control cannot be fixed by an abstract numerical formula; it depends entirely on the specialization of the task, the predictability of the environment, and the degree to which operational routines can be programmed into clear standard operating procedures[43].

Analytical Dimension	Empirical Reality
What the Group Said It Did	Administrative hierarchies maintain that vertical chains of command execute executive decisions reliably down to the operational front line[38].
What the Record Shows It Did	Information is filtered, modified, and politicized at every administrative level[46]. Frontline personnel routinely develop informal, undocumented routines (*street-level bureaucracy*) to cope with contradictory top-down directives[43].
What Modern Scholarship Infers	Organizational scale is constrained by an administrative trade-off: an organization can minimize executive cognitive overload (narrow span) or minimize cumulative informational distortion (flat hierarchy), but structural friction prevents it from eliminating both[43].

Rung	Population Range	Operational Status	Structural Outcome and Failure Mechanics
Household	4 to 10	Operated poorly	Overly formal administrative protocols introduce unnecessary friction into intimate domestic partnerships.
Hamlet or Band	30 to 50	Worked	Single-tier team; executive oversees 4 to 5 project leads effectively[7].
Village	150 to 500	Worked	Standard three-tier hierarchy (Executive -> 5 Supervisors -> 30 Workers per unit); highly stable[38].
Parish or District	1,500 to 5,000	Worked	Requires 4 to 5 administrative levels; control loss begins to degrade frontline performance[46].
Town or Watershed	15,000 to 50,000	Operated with friction	Bureaucracy expands; departmental silos emerge; communication across branches breaks down without automated logging systems[43].

Region or Bioregion	0.5 to 5 million	High failure rate	Susceptible to structural ossification, massive resource misallocation, and predatory bureaucratic rent-seeking[43].
Nation or Continent	50 to 500 million	Highly vulnerable	Severe agency loss; requires massive internal surveillance apparatuses to track bureaucratic compliance[46].
Planet	8 billion	Never achieved stably	Unmanageable vertical distortion and systemic breakdown.

Capture Test: Classical Managerial Hierarchy

A dark-triad personality captures a tall administrative hierarchy by positioning themselves at an informational bottleneck[46]. By exploiting Williamson's control loss, the bad actor filters operational data traveling upward, praises the executive lavishly, blames frontline workers for organizational failures, and marginalizes honest peers[46].

A historical case was the managerial capture of the Soviet Ministry of Light Industry under the *Glavok* system (1960–1985). Enterprise managers and regional directors routinely reported 100% quota fulfillment by systematically altering production figures while manufacturing unusable goods. Higher echelons received sanitized reports, while whistleblowers were fired or prosecuted for disrupting party consensus.

Structural defenses against this dynamic include unannounced direct inspections bypassing the administrative chain of command, independent auditor channels reporting directly to an oversight assembly, and radical horizontal visibility where raw production ledgers are open to all personnel[43].

Collective Action, Common-Pool Resources, and the Heterogeneity Paradox

In *The Logic of Collective Action* (1965), Mancur Olson demonstrated that rational, self-interested individuals will not act to achieve group interests unless the group is small, or unless selective incentives or coercive measures are introduced[48]. Olson established a taxonomy of group scales:

- Privileged Groups (Extremely Small): At least one member derives sufficient personal benefit from the public good to bear the entire cost of providing it unilaterally.
- Intermediate Groups (Small): No single member captures enough gain to fund the public good alone, but actions are directly visible to peers; defection is noticed, allowing coordination through mutual bargaining.
- Latent Groups (Large): An individual's contribution or defection produces an imperceptible effect on the aggregate outcome. Free-riding becomes the dominant personal strategy; without centralized coercion or private side-payments, collective action fails.

Olson's thesis established the traditional rule of political economy: **smaller groups are inherently more effective at organizing collective action than large groups.**

Ostrom, Agrawal, and the Inverted-U Curve

Elinor Ostrom (1990) in *Governing the Commons* and Arun Agrawal (2000, 2001) challenged the assumption that smaller groups are universally superior in common-pool resource (CPR) systems[48]. Agrawal evaluated the historical performance of the *Van Panchayats* (village forest councils) of the Kumaon Himalaya in northern India[49].

Following local resistance against British colonial forest enclosures, the colonial state enacted the Kumaon Forest Panchayat Act of 1931[51]. The legislation transferred legal ownership of local forests to democratically elected village councils[51]. Between 3,000 and 6,000 Van Panchayats have operated across the region for nearly a century, offering a natural laboratory for studying institutional scale[52].

Agrawal analyzed resource monitoring across village councils in Almora and Pithoragarh districts[49]. Contrary to Olson's thesis that smaller groups always manage commons better, Agrawal identified an **inverted-U (quadratic) relationship** between user group size and institutional success[55]:

Group Size Tier	Demographic Scale	Enforcement Mechanism	Common-Pool Outcome and Failure Modes
Very Small Groups	< 15 households (< 80 people)	Rotating self-monitoring (*lattha*)[51]	**Failed.** Insufficient tax base to hire dedicated third-party guards (*chowkidars*); volunteer monitoring creates interpersonal friction and lapses[49].

Intermediate Groups	30 to 80 households (150 to 500 people)	Dedicated third-party guard funded by user fees[49]	**Optimal Success.** Sufficient financial resources to support professional monitors; compact enough for the general assembly to monitor guards and leaders[49].
Very Large Groups	> 100–150 households (> 800–1,000 people)	Distant committee or underfunded staff[55]	**Failed.** Olson free-riding multiplies; inter-hamlet monitoring costs become prohibitive; rule consensus collapses[51].

Agrawal and Sanjeev Goyal (2001) confirmed that institutional durability requires a budget surplus sufficient to hire dedicated third-party monitors (*chowkidars*)[49]. Very small groups cannot support this overhead, forcing members into rotating volunteer policing (*lattha panchayat*)[51]. In volunteer systems, social friction, kinship loyalties, and the high opportunity cost of missed agricultural labor lead to monitoring evasion and unchecked resource depletion[49].

The Heterogeneity Dimension

Ostrom (2002), Amy Poteete and Elinor Ostrom (2004), and Agrawal (2001) proved that user heterogeneity often exerts a stronger influence on commons outcomes than raw group size[58]. Heterogeneity functions across two distinct operational forms:

- Economic Heterogeneity (Endowments): Disparities in land holdings, livestock herds, or capital assets[59]. When large landowners derive the greatest absolute benefit from maintaining an irrigation canal or perimeter fence, they may willingly fund a disproportionate share of upkeep, stabilizing collective action[61]. However, if elite extraction strategies diverge from subsistence users—such as converting communal mixed oak forests into commercial timber—economic heterogeneity shatters the commons[52].
- Sociocultural Heterogeneity (Identities and Interests): Cleavages along caste, ethnic, religious, or political lines[59]. Sociocultural heterogeneity damages mutual trust and shared normative expectations[61]. Where ethnic or caste divisions align directly with economic inequalities, CPR governance frequently collapses regardless of group size[61].

Analytical Dimension	Empirical Reality
What the Group Said It Did	Van Panchayat councils claim to manage community forests through democratic equality, shared village stewardship, and fair distribution of fodder and fuelwood[51].
What the Record Shows It Did	High-caste households (*Brahmins* and *Rajputs*) frequently capture council leadership, directing guard patrols away from elite livestock foraging zones while levying heavy fines on low-caste (*Dalit*) women gathering daily cooking twigs[52]. Sustained performance depends on strict, institutionalized guard funding rather than communal goodwill[49].
What Modern Scholarship Infers	Successful commons governance requires balancing a resource's ecological scale with an administrative scale[48]. Institutional success depends on hiring non-kin third-party enforcement funded by collective contributions, which requires an intermediate community size (roughly 150 to 500 people)[49].

Rung	Population Range	Operational Status	Structural Outcome and Failure Mechanics
Household	4 to 10	Worked	Direct internal resource sharing; zero monitoring overhead.
Hamlet or Band	30 to 50	Operated with resource deficits	Too small to support dedicated third-party guards; volunteer

			monitoring collapses into personal resentment[51].
Village	150 to 500	Optimal performance tier	High social visibility combined with sufficient tax base to employ professional guards[49].
Parish or District	1,500 to 5,000	Operated only via nested federations	Single unstratified commons fail; requires multi-tier federated councils (*nested enterprises*, Ostrom Principle 8)[48].
Town or Watershed	15,000 to 50,000	Failed without nested tiers	Centralized watershed boards fail if they ignore autonomous village councils[48].
Region or Bioregion	0.5 to 5 million	Failed	Unchecked open-access dilemmas dominate without multi-layered polycentric jurisdictions[62].
Nation or Continent	50 to 500 million	Failed entirely as a direct commons	Centralized state ministries mismanage local forestry resources[49].
Planet	8 billion	Failed to date	Global open-access

			atmospheric and oceanic degradation.

Capture Test: Common-Pool Resource Governance

An opportunistic, dark-triad coalition captures a common-pool resource regime by securing leadership of the executive committee (e.g., the Sarpanch office), altering extraction quotas in favor of family parcels, diverting fines into private accounts, and using formal authority to punish challengers[52].

A documented historical case occurred in Almora district during the 1980s and 1990s[52]. Wealthy high-caste village leaders in several Van Panchayats formed alliances with regional timber and resin contractors[52]. They registered fictitious assembly votes to permit commercial harvesting in protected oak and chir-pine reserves, pocketing the royalties while legally barring lower-caste households from gathering essential leaf litter and fuelwood[52].

Defensive mechanisms that resisted capture included mandatory open-air public accounting of council funds, regular re-election of council seats by lot or demographic quotas, and accessible appeals to regional judicial magistrates where vulnerable users could contest corrupt local councils[48].

Plenary Assemblies and the Limits of Direct Face-to-Face Democracy

The direct democratic assembly represents the classic model of participatory governance[63]. Two empirical studies clarify the structural, cognitive, and social constraints on assembly scale: Frank M. Bryan's long-term research on New England town meetings and Mogens Herman Hansen's archaeological-demographic analysis of the Athenian *Ekklesia*[63].

Bryan's Vermont Town Meeting Dataset

In *Real Democracy: The New England Town Meeting and How It Works* (2004), Frank M. Bryan published findings from a 30-year empirical study of Vermont town meetings[63]. Bryan and his researchers observed and recorded **1,435 town meetings** across 210 Vermont towns between 1970 and 1998, compiling roughly 5,100 individual counts[64].

Registered Voter Pool (Town Scale)	Mean Attendance Rate (%)	Deliberation Quality and Demographic Equity
< 100 voters	45% – 60%	Broad public participation; high floor speech equity[64]
100 – 500 voters	25% – 35%	Robust deliberation; diverse occupational representation[64]

500 – 1,500 voters	15% – 20%	Floor speeches increasingly dominated by professionals[67]
1,500 – 3,000 voters	8% – 12%	Substantial participation drop; selective elite attendance[64]
> 3,000 voters	3% – 6%	Direct democracy transforms into an elite acclamation event[67]

Bryan established an inverse power-law relationship between population size and direct democratic participation[66]. As the number of registered voters grew:

- Attendance Collapsed: In the smallest towns (under 150 voters), average attendance ranged between 45% and 60%[64]. In larger towns (exceeding 3,000 voters), attendance fell below 8%[67].
- Floor Debate Contracted: In small assemblies, up to 50% of attendees participated verbally from the floor[67]. In assemblies exceeding 400 people, speaking was dominated by an educated, professional minority (less than 10% of those present)[64].
- Gender Speaking Equity Eroded: While women attended at rates equal to men (averaging 46% of attendees across the dataset), their share of spoken remarks declined as town size increased[63]. In larger assemblies, male professionals disproportionately occupied podium time[63].

Bryan concluded that direct democracy is constrained by human mechanics[64]. Effective deliberation requires a shared acoustic and psychological space where participants can read body language and speak without fear of public humiliation[64]. Beyond 200 to 300 assembled participants, plenary democracy shifts from participatory deliberation into theatrical spectacle[64].

The Pathology of Consensus in Small Assemblies

Small scale does not ensure egalitarian governance[64]. In *Beyond Adversary Democracy* (1980), Jane Mansbridge conducted an intensive ethnographic study of "Selby," a rural Vermont town of roughly 500 residents[63]. Mansbridge discovered that face-to-face assemblies can foster subtle forms of social exclusion:

- Intimidation and Conflict Avoidance: Many townspeople avoided attending or speaking at town meetings due to an intense fear of open confrontation with prominent neighbors[72]. In a small community, a public dispute over school budgets or property taxes can spill over into personal relationships, threatening store credit, childcare help, or casual employment[72].
- Hegemony of Vocal Elites: The insistence on unitary "consensus" silenced dissent[71]. Lower-status individuals chose silence rather than publicly challenging prominent

community leaders, allowing influential figures to push measures through with apparent unanimity[71]. Mansbridge observed that women contributed only 29% of spoken remarks, while high-status male landowners accounted for 71%[71].

The Upper Structural Limit: The Classical Athenian Ekklesia

The largest institutional direct democracy in history was the *Ekklesia* of Classical Athens (5th and 4th centuries BC)[75]. Mogens Herman Hansen (1983, 1991) documented the structural parameters of this system[65]:

- Total adult male citizen pool of Attica: 30,000 to 40,000 in the 4th century BC[77].
- Capacity of the Pnyx: Phase I (5th c.) accommodated roughly 6,000 citizens; Phase III (late 4th c.) held an estimated 13,800 citizens tightly packed onto the hillside[65].
- Quorum Requirements: A minimum of 6,000 citizens was legally required for sensitive sovereign votes, including ostracisms, naturalizations, and major political pardons[65].

Hansen identified the institutional technologies Athens used to prevent a mass assembly of 6,000 from collapsing into operational chaos:

- The Boule (Council of 500): The *Ekklesia* could not set its own agenda. Business had to be prepared by the Council of 500 (*Boule*), chosen by lot (*sortition*) from the demes[75]. The *Boule* drafted provisional decrees (*probouleuma*), preventing the mass assembly from degenerating into legislative confusion[75].
- Attendance Compensation (*Misthos Ekklesiastikos*): Introduced c. 403 BC by Agyrrhios after the Peloponnesian War, assembly pay was required to motivate poor rural farmers to walk miles to the Pnyx[75]. To control expenditures, only the first 6,000 citizens to arrive received compensation, after which attendants sealed the entrances with a dyed red rope[75].
- Separation of Deliberation and Legislation (*Nomothetai*): After 403 BC, the mass assembly lost the authority to pass foundational laws (*nomoi*)[75]. General legislation was transferred to the *Nomothetai* (boards of 500 to 1,000 sworn citizens chosen by lot who sat for a single day), transforming the assembly into an electoral and foreign-policy forum while shifting law-making to smaller deliberative jury panels[75].

Analytical Dimension	Empirical Reality
What the Group Said It Did	Athens claimed that *isēgoria* (the equal right of every citizen to speak before the assembly) governed the polis, making the demos sovereign on the Pnyx[75].
What the Record Shows It Did	Speaking from the *bema* was restricted to a wealthy, highly educated class of professional orators (*rhētores*)[75]. The 6,000 assembled citizens primarily voted,

	shouted, heckled, or approved pre-drafted motions rather than formulating policy collaboratively[65].
What Modern Scholarship Infers	An assembly of 6,000 is not a deliberative body; it is an acclamation and veto body[65]. Direct democracy at the scale of thousands functions only when paired with sortition-based agenda-setting councils (*the Boule of 500*) and specialized judicial vetting panels[75].

Rung	Population Range	Operational Status	Structural Outcome and Failure Mechanics
Household	4 to 10	Worked	Informal domestic coordination.
Hamlet or Band	30 to 50	Worked	Full deliberative direct democracy; all voices can be heard; intimidation can be checked[64].
Village	150 to 500	Maximum deliberative tier	Operates well under formal parliamentary rules; requires procedural protections for vulnerable speakers[64].
Parish or District	1,500 to 5,000	Severe participation collapse	Attendance plummets to <10%; speaking becomes restricted to high-status professionals[64].

Town or Watershed	15,000 to 50,000	Failed as a deliberative body	The Athenian Pnyx threshold (~6,000 attendees); acts purely as an acclamation/veto body requiring representative agenda setters[65].
Region or Bioregion	0.5 to 5 million	Never tried	Physically impossible without broadcast communications.
Nation or Continent	50 to 500 million	Never tried	Pure direct assembly is unworkable.
Planet	8 billion	Never tried	Pure direct assembly is unworkable.

Capture Test: Direct Plenary Assembly

A charismatic demagogue captures a plenary assembly by using emotionally charged rhetoric to bypass institutional checks, stoking populist hostility against internal minorities, and rushing catastrophic motions through a panicked crowd[75].

A documented historical case occurred in 427 BC during the Peloponnesian War, when the demagogue Cleon convinced the Athenian *Ekklesia* to execute all adult male citizens of rebellious Mytilene and enslave its women and children (Thucydides, *History of the Peloponnesian War*). The following morning, horrified by their impulsive decree, the assembly reconvened, condemned Cleon's rhetoric, and dispatched a second trireme to halt the massacre. Later, in 415 BC, Alcibiades manipulated the assembly's enthusiasm to launch the disastrous Sicilian Expedition, crippling Athens' defensive military power.

Athenian institutional defenses included the *Graphē Paranomōn* (a legal writ allowing any citizen to prosecute an assembly orator for proposing an unconstitutional or destructive measure, with penalties including massive fines or execution for convicted demagogues), compulsory multi-day cooling-off delays before confirming irreversible military verdicts, and secret balloting with voting pebbles (*psephoi*) to protect citizens from public intimidation.

Urban Scaling: Physical Agglomeration versus Network Coordination

When human settlements grow beyond rural farming bounds into dense urban aggregations, population scale alters the structural economics of the community[80]. The mathematical foundations of this transition were formulated by Luís M. A. Bettencourt, Geoffrey West, José Lobo, and their colleagues at the Santa Fe Institute (2007, 2013) in their theory of urban scaling[37].

Bettencourt proved that across historical eras and geographical regions, macro-level urban metrics scale as a power-law function of resident population[37]:

$$Y(N) = Y_0 N^{\beta}$$

Where N represents population size, $Y(N)$ is an aggregate socioeconomic or infrastructural metric, Y_0 is a baseline constant, and β is the scale-invariant exponent[37].

Scaling Regime	Exponent Range	Physical / Social Metric Examples	Operational Dynamics
Sublinear Regime	$\beta \approx 0.85 \quad (5/6)$	Road surface, water pipes, electrical cabling, storage nodes[37]	**Infrastructure Savings.** A doubling of population requires only an ~85% increase in physical distribution infrastructure[83].
Linear Regime	$\beta =$	Daily caloric intake, domestic water consumption, basic shelter[37]	**Biological Needs.** Raw per-capita physiological survival demands scale strictly 1:1 with population[37].
Superlinear Regime	$\beta \approx 1.15 \quad (7/6)$	Patent production, specialized trade, GDP, wealth, violent crime, contagion rates[37]	**Interaction Outputs.** A doubling of population yields an ~115% increase in both creative network output and

			destructive social friction[37].

The mathematical tension between sublinear and superlinear scaling creates a dual challenge for human settlements[37]:

- The Energetic Driver: High density saves material infrastructure, reducing per-capita transit distances and physical capital costs[37].
- The Coordination Friction: Social interactions expand superlinearly, generating innovation and economic specialization, but also driving identical superlinear increases in violent crime, property disputes, and pathogenic transmission[37].

Implications for Post-Collapse Governance

Bettencourt's formulation assumes continuous, motorized transit systems and stable communications networks that allow human populations to mix freely across urban space[37]. When industrial supply chains, motorized transit, and electrical power grids fail, the sublinear infrastructure savings ($\beta \approx 0.85$) collapse[37]. Maintaining paved road surfaces, stone aqueducts, and deep drainage works without motorized earthmovers or industrial pipes demands massive, exhausting manual labor[81].

Simultaneously, the superlinear penalty ($\beta \approx 1.15$) for violent crime and epidemic disease accelerates[80]. Concentrating thousands of post-collapse survivors into a dense, unmechanized urban area yields higher crime rates, faster disease spread, and severe water contamination without providing the material infrastructure efficiencies of modern cities[80]. Without industrial logistics, urban aggregations become demographic sinks that threaten self-governance[80].

Critique and Methodological Limits

Cosma Shalizi (2011) and Marc Barthelemy (2016) challenged the universality of Bettencourt's power-law exponents[83]. Shalizi demonstrated that estimating β is sensitive to metropolitan boundary definitions (the Modifiable Areal Unit Problem, MAUP)[37]. Depending on whether a researcher defines a city by its historical administrative core or its wider commuting basin, the calculated exponent can swing from linear ($\beta = 1.0$) to superlinear ($\beta = 1.25$)[83]. Furthermore, historical research on pre-industrial cities shows that high mortality and sanitation burdens routinely overwhelmed urban productivity, requiring continuous rural migration to maintain baseline population levels.

Analytical Dimension	Empirical Reality
What the Group Said It Did	Urban leaders argue that dense city populations maximize economic production, high culture, and social development[80].

What the Record Shows It Did	Throughout history, urban density consistently created high disease burdens, sanitation crises, and elevated crime rates, requiring coercive policing to preserve order[80].
What Modern Scholarship Infers	Urban agglomeration exhibits mathematically predictable returns to scale driven by social interaction networks, but the positive returns (wealth, innovation) and negative externalities (crime, disease) share identical mathematical dynamics ($\beta \approx 1.15$)[80].

Rung	Population Range	Operational Status	Structural Outcome and Failure Mechanics
Household	4 to 10	Worked	Basic domestic unit.
Hamlet or Band	30 to 50	No scaling effects	Purely linear dynamics; network density is too low for agglomeration effects[81].
Village	150 to 500	No scaling effects	Simple division of labor; low infectious load; minimal infrastructure savings[81].
Parish or District	1,500 to 5,000	Incipient urban inflection	Early artisanal specialization; localized water/waste management challenges appear[83].

Town or Watershed	15,000 to 50,000	Full urban scaling	Sublinear infrastructure savings emerge alongside superlinear crime and epidemic vulnerabilities[80].
Region or Bioregion	0.5 to 5 million	Operated with friction	Highly vulnerable without high-throughput supply chains; post-industrial regions de-urbanize toward this scale.
Nation or Continent	50 to 500 million	Modern industrial scale	Completely dependent on fossil fuels and high-speed transit networks.
Planet	8 billion	Modern global economy	Extreme systemic vulnerability to critical supply-chain disruptions.

Capture Test: Urban Agglomeration Governance

In dense urban settlements, predatory actors take over by seizing critical infrastructural bottlenecks—such as grain warehouses, centralized water mills, aqueducts, or defensive city gates—transforming public municipal assets into tools for private extortion.

A documented historical case occurred during the rise of the *Signoria* in late-medieval Italian communes (such as the Della Scala family in Verona, 1262–1387, and the Visconti in Milan, 1378–1402). As commercial towns expanded, factional violence between merchant oligarchs and craft guilds paralyzed consensual city councils. Opportunistic military captains (*podestà* or *capitano del popolo*) seized municipal grain reserves and fortified gates, using mercenary retinues to suppress civic assemblies and convert communal governance into hereditary autocracies.

Defenses that resisted such capture included dispersing essential grain storage across neighborhood wards, organizing citizen militias rooted in residential guilds rather than hiring mercenary troops, and decentralizing water supplies into neighborhood-managed cisterns that

could not be interdicted from a single point of failure.

Structural Inflection Thresholds: Cognitive Constants versus Institutional Prostheses

Human governance cannot rely on a single institutional model across scales. As populations grow, the structural mechanisms required to preserve stability shift predictably across discrete thresholds.

Population Scale	Primary Decision Mode	Institutional Mechanism	Cognitive and Physical Constraint
1 to 15	Informal Talk	Immediate conversational consensus	Working memory, empathy, emotional tracking[6]
15 to 50	Face-to-Face Deliberation	Reverse dominance leveling[15]	Acoustic reach, vigilance against bullying[16]
150 to 500	Plenary Assembly	Formal parliamentary rules, voting[64]	Dunbar active boundary; speaking floor limits[4]
1,500 to 5,000	Delegated Councils	Sortition, representation, paid guards[49]	Geographic transit friction; monitoring costs[55]
15,000 to 50,000	Polycentric Federation	Codified laws, specialized courts[48]	Anonymity; infrastructural chokepoints[43]
0.5M to 5M	Bureaucratic Federation	Multi-tier administrative departments[43]	Williamson control loss; courier transmission lag[46]
50M to 500M	Imperial / Representative	Standardized legal codes, ideological alignment	Mass communication limits; enforcement costs[46]

8 Billion	International Treaties	Polycentric pacts, trade agreements	Systemic coordination failures; global commons dilemmas[48]

The Four Fundamental Decision Modes

1. **Informal Talk and Daily Consensus (Scales 1 to 50):** Governance is embedded directly in daily foraging, agriculture, and shared domestic living[16]. Leadership is situational, non-coercive, and fluid[16]. Interpersonal disputes are resolved through unwritten social customs, humor, and collective peer pressure[15].
2. **Plenary Assembly and Formal Procedure (Scales 150 to 500):** Direct social monitoring breaks down as populations reach Dunbar's active boundary[1]. Governance requires scheduled assemblies, recognized meeting places, structured agendas (warnings), and procedural conventions to manage speaking turns and prevent shouting matches[64]. Voting transitions from informal consensus to public shows of hands or secret ballots[67].
3. **Delegation, Sortition, and Specialized Councils (Scales 1,500 to 5,000):** Assemblies of this size can no longer deliberate directly[64]. Direct democracy yields to representative institutions[64]. As illustrated by the Athenian *Boule* of 500, governance shifts to delegated administrative councils chosen by lot (*sortition*) or geographic representation, tasked with administrative oversight, military readiness, and judicial dispute resolution[75]. Third-party, specialized monitors (e.g., *Van Panchayat* forest guards) must be funded via collective assessments to prevent free-riding[49].
4. **Polycentric Federalism and Codified Bureaucracy (Scales 15,000 and above):** Face-to-face accountability is impossible[64]. Governance requires formal codified law, standardized property definitions, written financial accounting, and distinct institutional jurisdictions operating across nested scales[48].

Cognitive Constants versus Cultural Technologies

The boundaries separating these governance modes reflect a division between neurobiological limits and institutional technologies[14]:

- The Cognitive Constants: Human working memory, emotional bandwidth, and facial-processing capacity are biologically constrained[1]. An individual cannot maintain empathy-driven, reciprocally tracked relationships with more than roughly 150 people[1]. Similarly, human working memory and attention restrict an administrator's direct span of control over complex, interdependent tasks to 3 to 7 subordinates[38]. The acoustic dynamics of human vocalization and attention restrict deliberative assemblies to several hundred participants before podium dominance becomes unavoidable[64].
- The Cultural Technologies: Humans overcome these biological boundaries through institutional innovations that function as organizational prostheses[4]. Standardized legal codes, double-entry bookkeeping, property boundary markers, religious covenants,

sortition, and representative assemblies allow societies to coordinate millions of strangers without requiring direct personal relationships[28].

When post-industrial collapse destroys modern communication and energy infrastructure, complex bureaucratic institutions fail[81]. Human communities fall back on baseline cognitive constraints, making small, nested scales essential for stable self-governance[4].

Comparative Matrix of Governance Scaling

Governance Model	Primary References	Minimum Viable Scale	Cognitive / Structural Ceiling	Primary Capture Vector	Core Countermeasure
Reverse Dominance Council	Boehm (1999); Lee (1979)[15]	15 individuals[7]	~50 to 150 individuals[4]	Physical bullying, spiritual intimidation[16]	Communal ridicule, ostracism, coalitional execution[15]
Hutterite Bruderhof	Hostetler (1974); Peter (1987)[23]	~60 individuals	~150 individuals (fission trigger)[23]	Autocratic lineage capture, elder asset monopoly[24]	Colony split by lot, ministerial sortition[24]
Centurial Hierarchy	Le Bohec (1994); Marshall (1947)[33]	8 individuals (*contubernium*)[33]	Span of 3–6 units per echelon[38]	Praetorianism, warlordism (*caudillismo*)	Rotational commands, civilian logistical control
Managerial Hierarchy	Graicunas (1933); Williamson (1967)[38]	3 individuals	5–7 direct reports; 4–5 tiers max[38]	Information gatekeeping, flattery, metric tampering[46]	Direct unannounced audits, horizontal transparency[43]
Common-Pool Regime	Ostrom (1990); Agrawal (2001)[48]	30 households (~150 people)[55]	~80 to 100 households (~500 people)[55]	Elite capture, logging/water extraction	Paid non-kin guards, open financial

				diversion[52]	auditing[48]
Plenary Assembly	Bryan (2004); Mansbridge (1980)[63]	~30 individuals[67]	~250 deliberative; 6,000 voting[65]	Demagoguery, intimidation of dissenters[72]	Sortition agenda councils, secret balloting, *Graphē Paranomōn* [cite: 75]
Polycentric Federation	Ostrom, Tiebout & Warren (1961)[62]	~1,500 individuals	Continental / Regional scale	Inter-jurisdictional cartelization, federal overreach	Jurisdictional competition, citizen exit rights[62]

Summary of Robust Findings

1. Personal social networks organize into nested emotional tiers scaling by a factor of roughly three (5, 15, 50, 150, 500, 1,500)[6].
2. Direct, unwritten reputational monitoring functions reliably only up to approximately 150 individuals[1].
3. Communal property regimes experience rising lineage conflict above 130 to 150 members, requiring institutional fission[23].
4. Military command structures across cultures converge on teams of 4–8, tactical units of 80–120, and operational battalions of ~500[33].
5. Executive spans of control over complex tasks degrade beyond 5 to 7 direct reports due to exponential relational combinations[38].
6. Vertical hierarchies suffer systemic control loss, losing roughly 10% to 15% of information fidelity per organizational tier[46].
7. Common-pool resource governance displays an inverted-U curve: very small groups cannot fund enforcement, while very large groups face prohibitive transaction costs[55].
8. In direct plenary assemblies, attendance rates and speaking equity collapse as the electorate expands beyond 200 to 300 citizens[64].
9. Face-to-face small groups often suppress minority dissent through social intimidation, enforcing a false consensus[71].
10. Urban settlements exhibit superlinear increases ($\beta \approx 1.15$) in both socioeconomic productivity and destructive externalities (crime, disease)[80].

Contested and Open Questions

The degree to which Dunbar's 150 boundary is an unyielding neurological ceiling rather than a

flexible cultural artifact remains contested[4]. While Dunbar maintains that temporal limits on grooming and conversation constrain active social networks, critics demonstrate that phylogenetic regressions yield vast confidence intervals, suggesting that group scale is heavily shaped by local ecology and economic production[4].

In common-pool resource governance, the exact relationship between economic inequality and collective action remains unresolved[59]. While Olson's theory suggests that large asset owners may stabilize public goods by absorbing maintenance costs, empirical field studies reveal that economic disparities frequently allow local elites to redirect resources toward private commercial gain, destroying community solidarity[52].

A third open problem centers on whether direct democratic assemblies can deliberate effectively beyond several hundred citizens without reverting to sortition or representative bureaucracy[64]. While sortition prevents factional capture in city-scale bodies, whether sortition councils can maintain political legitimacy across non-literate, post-collapse rural districts remains untested[28].

Finally, the applicability of Bettencourt's urban scaling laws under conditions of industrial collapse remains debated[37]. Scholars contest whether pre-industrial and post-collapse settlements retain the sublinear infrastructure savings observed in electrified modern cities, or whether manual maintenance burdens eliminate scale advantages entirely[81].

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Implementability after the Fall

Household Unit (4 to 10 People)

At the household rung, governance functions through informal, conversational coordination between adult partners and kin. Labor, meals, and safety precautions are allocated through daily dialogue without formal voting or written legalities. Conflict is resolved through domestic suasion and mutual dependency.

To operate effectively, the household requires a defensible physical dwelling, access to potable water, personal hand tools, and a secure food storage cache.

The primary failure mode to expect is domestic autocracy, neglect, or violent abuse by a dominant family member. In isolated post-collapse homesteads, despotic behavior cannot be checked or sanctioned by external kin or neighbors, leaving vulnerable family members without institutional recourse.

Village Community (300 People)

At 300 individuals, a community surpasses Dunbar's cognitive limit[1]. It cannot govern itself as an informal, unwritten collective[23]. An attempt to run a 300-person settlement through pure

consensus will lead to lineage factions, unaddressed theft, and elite capture[23].
The minimum viable institutional structure requires:

- A Plenary Assembly: Meets bi-monthly to vote on communal regulations, major capital investments, and seasonal resource boundaries[64]. Decisions must be made by majority show of hands or token balloting, with clear speaking limits to prevent orator dominance[64].
- An Executive Selectboard: A council of 5 to 7 individuals chosen annually by lot (*sortition*) from eligible household heads, rotating off each term[38]. This body directs daily labor squads, settles boundary disputes, and manages common grain reserves[38].
- Dedicated Third-Party Guards (*Chowkidars*): Following Agrawal's inverted-U findings, the village must levy a small, mandatory grain tax to support two permanent watchmen tasked with perimeter defense and monitoring community woodlots and water sluices[49]. Relying on rotating volunteer policing creates social friction and enforcement breakdowns[49].

Initial infrastructure requirements include:

- A Durable Ledger: A bound physical book containing land boundaries, tool inventories, tax contributions, and council judgments[48].
- A Shared Calendar: A central sun-dial, village bell, or public calendar board coordinating assembly days, canal cleaning, planting cycles, and guard shifts[48].
- A Meeting Space: A weather-proof barn or covered amphitheater accommodating 200 adults within clear acoustic and visual range[64].

The primary failure mode to expect is factional lineage conflict[23]. Two or three large extended families will form alliances to dominate the council, shield their relatives from guard penalties, underreport their harvests, and shift defense duties onto isolated households[52].

District Organization (3,000 People across ~10 Villages)

A direct mass meeting of 3,000 citizens cannot deliberate effectively; it becomes an acclamation rally vulnerable to demagogic manipulation[64]. The district must be structured as a polycentric federation (Ostrom's Principle 8)[48]:

- District Council of Delegates: A 10-to-20-member assembly formed by two representatives sent from each village council[38]. Delegates carry explicit, revocable instructions from their home settlements.
- Specialized Task Boards: Small administrative boards (3 to 5 members) overseeing inter-village infrastructure: watershed irrigation canals, trade road security, bridge maintenance, and collective defense militias[38].
- Appellate Judicial Panel: A mobile body of five elders chosen by sortition across the district to mediate inter-village disputes, deterring retributive feuds[48].

Initial infrastructure requirements include:

- Standardized Metrology: Physical reference weights and volume containers maintained at the district market to prevent trade disputes between villages.
- A Scheduled Courier Route: A runner or rider traveling once or twice weekly along fixed trails to exchange defense alerts and market schedules.

- Neutral Meeting Ground: A central fairground or crossroads market outside the territory of any single village, preventing local intimidation during deliberations.

The primary failure mode to expect is upstream-downstream resource conflict[48]. Upstream villages will divert shared river water or clear protective watershed timber during dry spells, ignoring district warnings and daring downstream settlements to respond with force[48].

Principles

1. A direct, face-to-face peer group cannot exceed roughly 150 individuals without developing informal sub-coalitions that undermine consensus governance[4].
2. Increasing an administrator's direct subordinates beyond seven exponentially multiplies interpersonal cross-relationships, causing managerial cognitive overload and coordination failure[38].
3. Every vertical tier added to an administrative hierarchy reduces the informational fidelity of operational instructions and feedback by an estimated 10% to 15%[45].
4. Common-pool resource governance fails in very small communities (<15 households) due to an inability to fund third-party enforcement, and fails in very large communities (>150 households) due to runaway transaction costs[51].
5. Direct plenary assemblies with more than 300 participants cease to function as deliberative bodies and turn into acclamation forums dominated by elite orators[64].
6. In unconstrained direct assemblies, social pressure to preserve harmony suppresses minority dissent, allowing aggressive leaders to establish de facto oligarchic control[71].
7. The emergence of social and economic inequality among common-pool resource users undermines cooperation unless institutional rules align elite investment incentives with sustainable collective maintenance[59].
8. Dense population centers produce superlinear increases ($\beta \approx 1.15$) in social interaction and specialized production, but generate identical superlinear increases in violent crime and pathogen transmission[37].
9. Broad regional federations maintain institutional stability over deep time only if local baseline units retain the constitutional authority to craft, monitor, and sanction their own internal rules[48].
10. The selection of executive council members by lot (*sortition*) prevents dark-triad personalities from monopolizing public offices far more reliably than competitive elections[28].

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