11.479J / 1.851J Water and Sanitation Infrastructure in Developing Countries
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Sewage Collection Systems

by:

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MIT 11.479 - Water and Sanitation in Developing Countries

Definition of Sanitation

Services or systems of collection, transportation, treatment, and sanitary disposal of wastewater, excreta, or other waste.

(Pan American Health Organization/World Health Organization, 2001)

Definition of Sewerage

A system of pipes for wastewater collection and removal.

(Pan American Health Organization/World Health Organization, 2001)

Major Parts of a Conventional Sewer

- Large: interceptors, trunks, mains
- Small: laterals, branches, house connections
- Manholes, clean-outs, junction boxes
- Grease traps
- Odor control facilities
- Wet weather storage
- Pump stations

Conventional Sewerage Assumptions

- Houses face the street and are laid out regularly on city blocks.
- Houses are connected individually to a sewer located in the street.
- Streets are paved and of ample width to allow vehicle access by personnel who maintain the sewer lines.
- Relatively large-diameter sewer pipes are installed at conservative design slopes and depths.
- Suitable equipment and materials are available to construct and maintain the system.
- The collected sewage is discharged to a suitable destination, such as a wastewater treatment plant.

Source: Nance, 2004.

Technical Challenges to Sewers

- Houses constructed without underground infrastructure, no bathrooms
- Houses constructed in areas with poor drainage, soils, topography, high water table
- Complementary infrastructure not in place (no pavement, no drains, intermittent or no water)
- Irregular housing layouts, narrow paths, indistinct blocks, high density
- Inaccessible to construction equipment and maintenance trucks
- Conservative design criteria

Source: Nance, 2004.

Financial Challenges to Sewers

- High capital costs (expensive materials and equipment, high excavation and treatment costs)

- High maintenance costs (expensive equipment, trained personnel)

- Fees unaffordable to most residents, govt. subsidies go to middle and upper income

- Inadequate public investment

- Inadequate private investment

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Source: Nance, 2004.

Social Challenges to Sewers

- People don't understand the relationship between sewer infrastructure and disease
- Low public demand relative to other needs
- Fear/apathy/mistrust of govt. officials
- Low willingness to pay
- Ability to find individual solutions reduces perception of community level problems
- Need for educational and promotional campaigns

Source: Nance, 2004.

Source: Nance, 2004.

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Source: Nance, 2006.

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Source: Nance, 2006.

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Source: Nance, 2006.

The Sewerage Problem

- Generally low rates of sewer coverage
- Generally poor performing sewer systems
- A geographic patchwork of sewer service sharply differentiated by income

Source: Nance, 2004.

Appropriate Sewerage

- Appropriate technology fits local circumstances (costs, culture, know-how).
- Neighborhood and block scale sanitation projects are common in Latin America.
- Decentralized treatment or none is the norm.
- Intense community involvement since the 1980s.
- Condominial sewers are unique to Brazil, a genuine experiment, not technology transfer.

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Source: Nance, 2004.

Appropriate Sewerage Options

- Settled sewers (small bore, solids free)
- Simplified sewers (condominial, shallow)

House connection

Interceptor tank
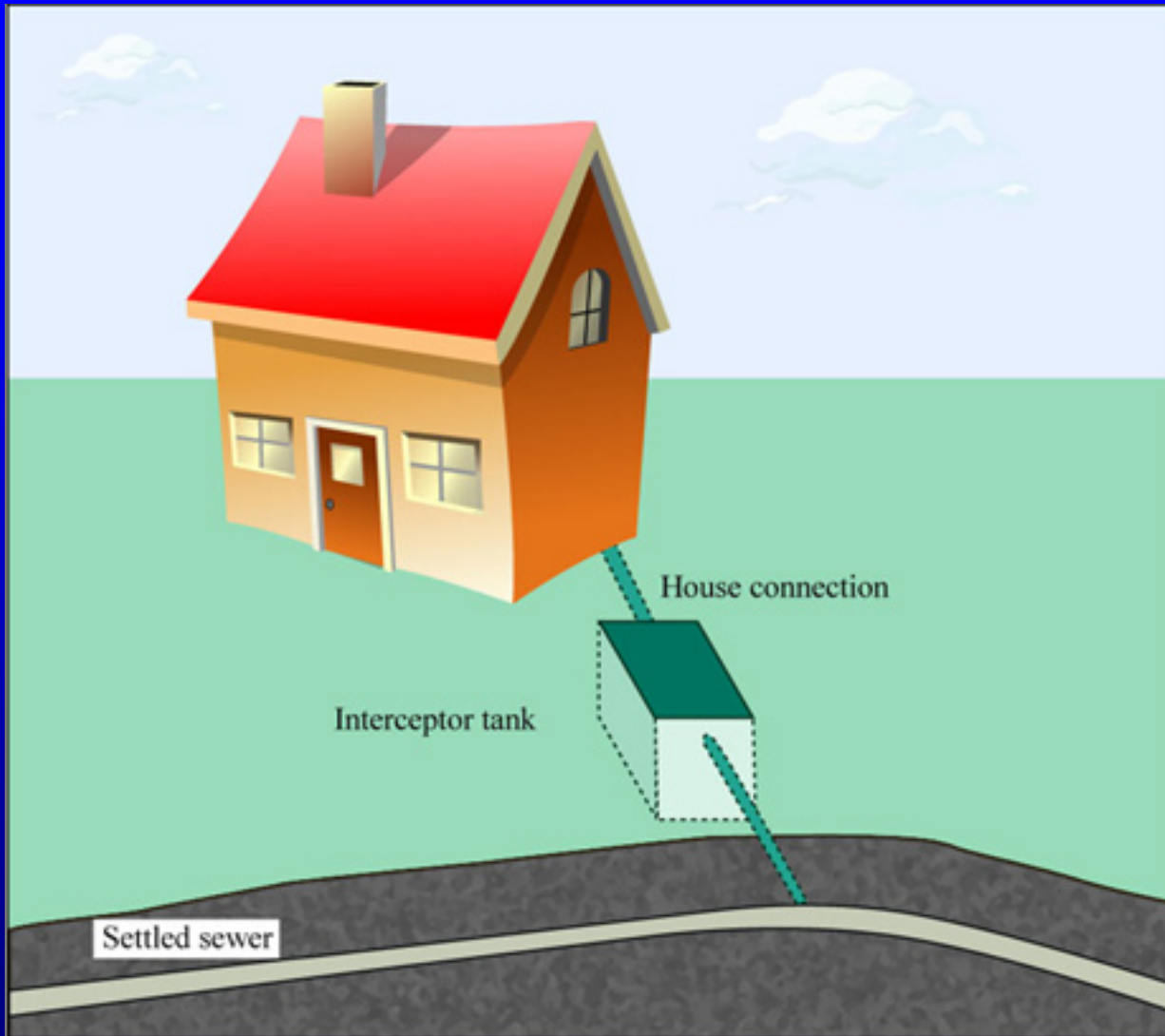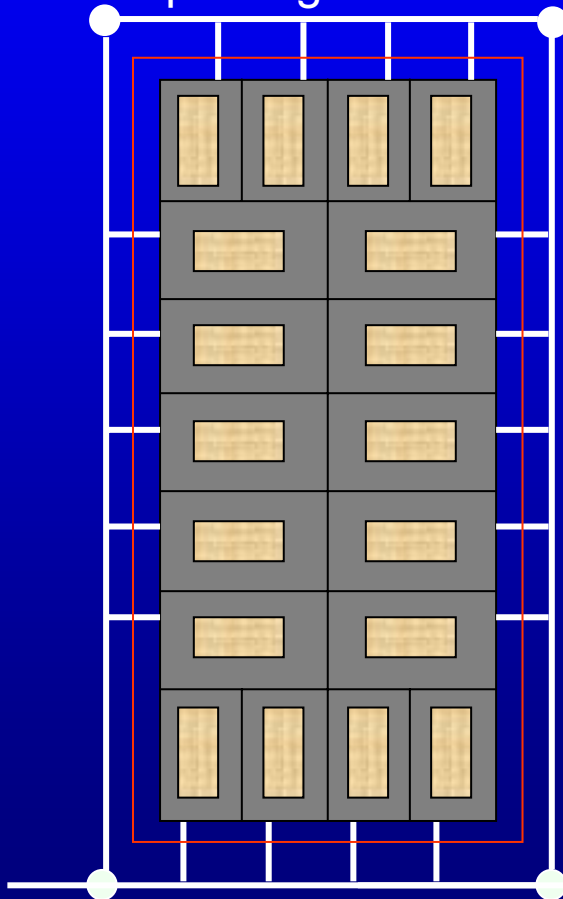
Settled sewer

Figure by MIT OpenCourseWare.

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Source: Mara, 1996.

Sewer System Piping Layouts

Conventional
Pipe length = 100%

Condominial
Pipe length = 60%
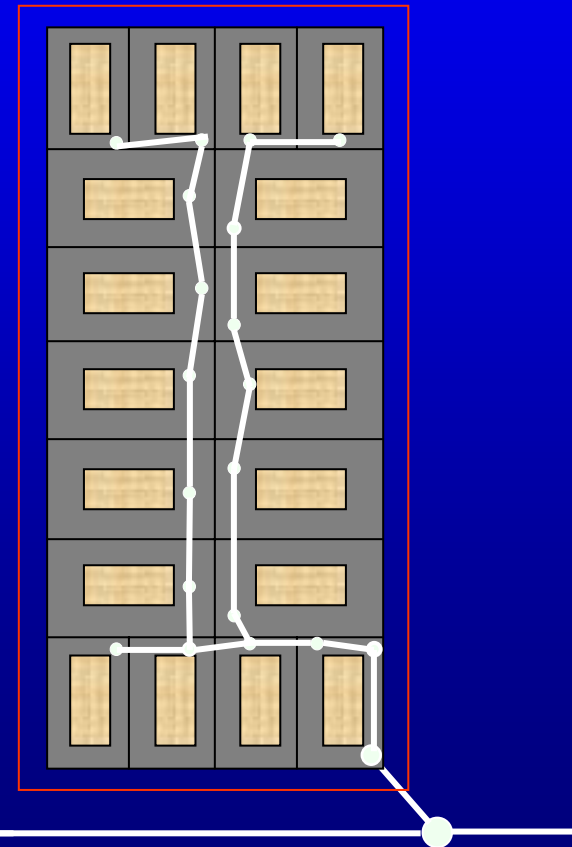
Source: Nance, 2004.

Design Item	Typical Condominial Design Standards	Typical Conventional Design Standards
Design Period	15 - 20 years	25 - 50 years
Peaking Factor (unitless)	1.8	2.0 - 3.3
Minimum Self-Cleaning Velocity	Not typically used	0.5 – 0.6 m/s
Maximum Velocity	4 m/s	3 – 6 m/s
Minimum Tractive Tension[b]	0.1 kg/m^2 or 1 Pa	Not typically used
Minimum Flow Depth	0.20 x diameter	0.20 x diameter
Maximum Flow Depth	0.75 x diameter	0.75 x diameter
Minimum Design Flow	100-120 L/day/person	1500 L/day/person
Minimum Depth of Sewer	0.60 – 1.5 m	1.8 m

Source: Nance, 2004.

| Design Item	Typical Condominial Design Standards	Typical Conventional Design Standards
Maximum Manhole Spacing	Not typically used	100 – 180 m
Minimum Manhole Diameter	0.6 – 0.9 m	1.5 m
Minimum Depth of House Connection	0.4 m	0.8 m
Minimum Diameter	100 mm (house connections and block sewers) 150 mm (block collectors and trunk sewers)	150 - 200 mm
Minimum Slope	0.5% – 0.6% (0.005 – 0.006 m/m)	1.0% – 1.4% (0.01 – 0.014 m/m)
Typical Number of Homes per Collective Sewer or Street Lateral	10-60 homes for 100 mm diameter at min. slope and min. tractive tension	20 homes for 100 mm diameter at min. slope and min. velocity
Maximum Length of Pipe per Collective Sewer	400 m for 100 mm diameter at min. slope	Not typically used

Source: Nance, 2004.

Condominial Sewers

Source: Nance, 2004.

Condominial Sewers
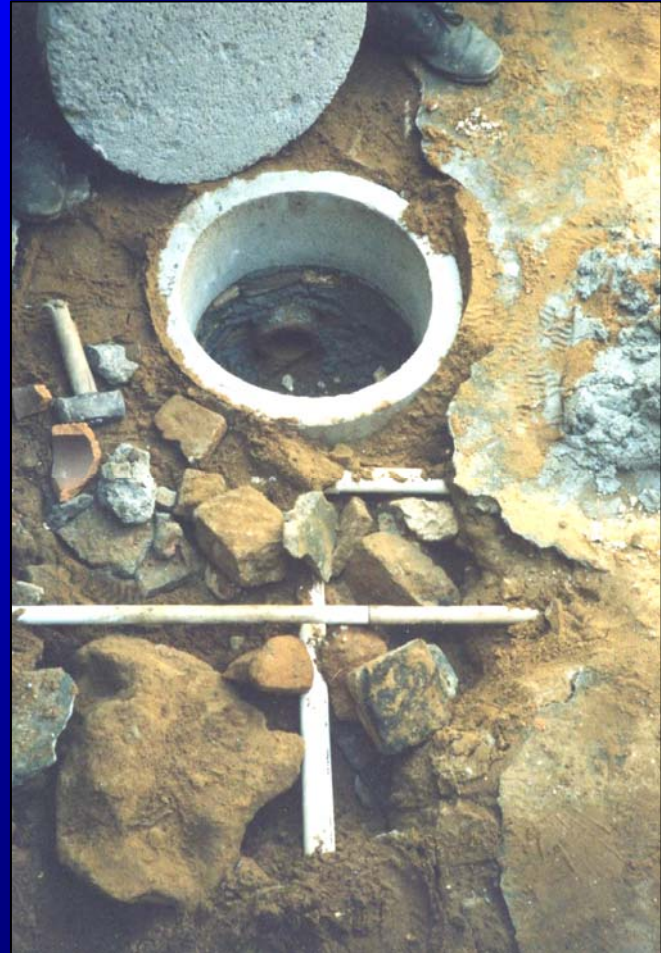
Source: Nance, 2004.

Condominial Sewers
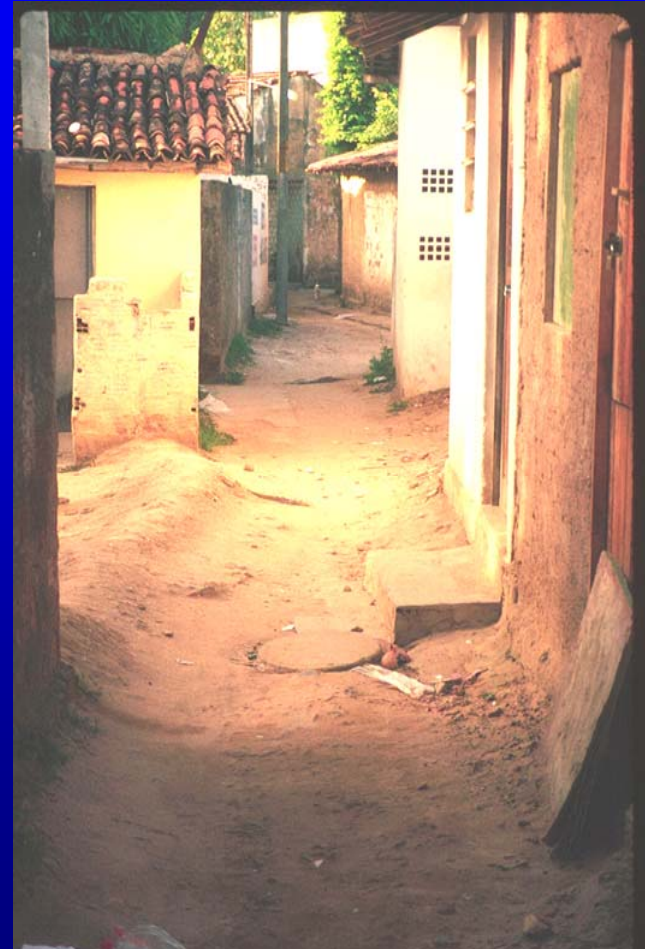
Source: Nance, 2004.

Source: Nance, 2004.

Brazil's Condominial Sewers

How do you define a condominial sewer?

"Physically, it is defined as a low cost system. Philosophically, it is defined by the participation of residents among themselves and by the public agency's actions to stimulate this participation."

Source: Nance, interview with Division Manager of the State Agency, Natal, 06/01/95.

Other Literature: Synnatamby, Wright, World Bank, Watson

Research Question

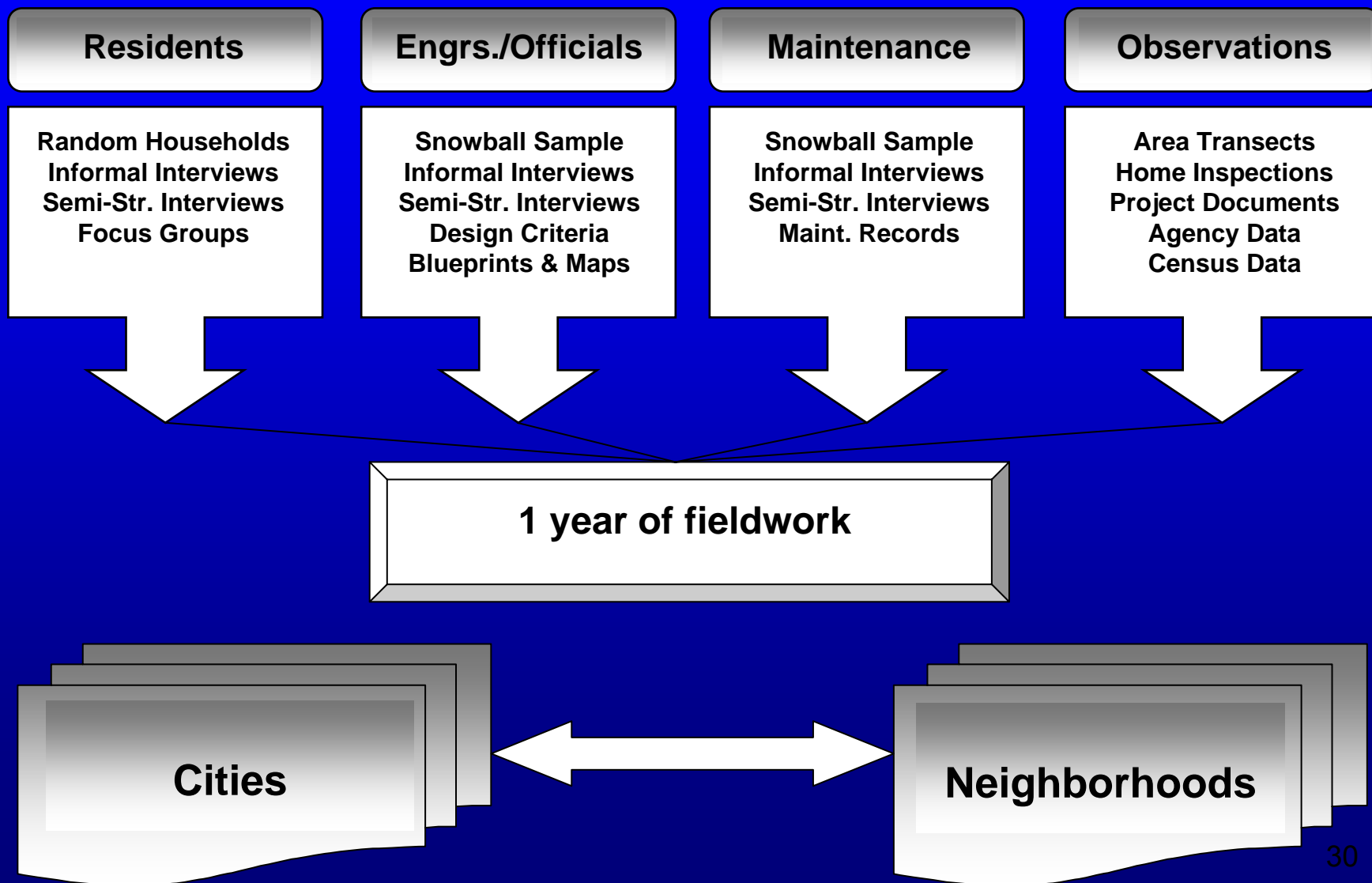*What factors enable good performance*

in condominial sewer projects?

Deficiencies in the Literature

- Few studies on urban sanitation

- Unexplored analysis of performance

- Little empirical research on participation in the sanitation sector

- Insufficient integration of contextual factors with conceptions of project delivery

Source: Nance, 2004.

Research Approach

- Address performance (not just coverage).

- Disaggregate participation.

- Look for factors that were important in the best and worst projects.

Source: Nance, 2004.

Research Methods

Residents	Engrs./Officials	Maintenance	Observations
Random Households Informal Interviews Semi-Str. Interviews Focus Groups	Snowball Sample Informal Interviews Semi-Str. Interviews Design Criteria Blueprints & Maps	Snowball Sample Informal Interviews Semi-Str. Interviews Maint. Records	Area Transects Home Inspections Project Documents Agency Data Census Data

1 year of fieldwork

Cities ⟷ **Neighborhoods**

Source: Nance, 2004.

Research Sites

Sewer Coverage

Recife (1995): 24%

Natal (1995):   19%

Map of Brazil removed due to copyright concerns.
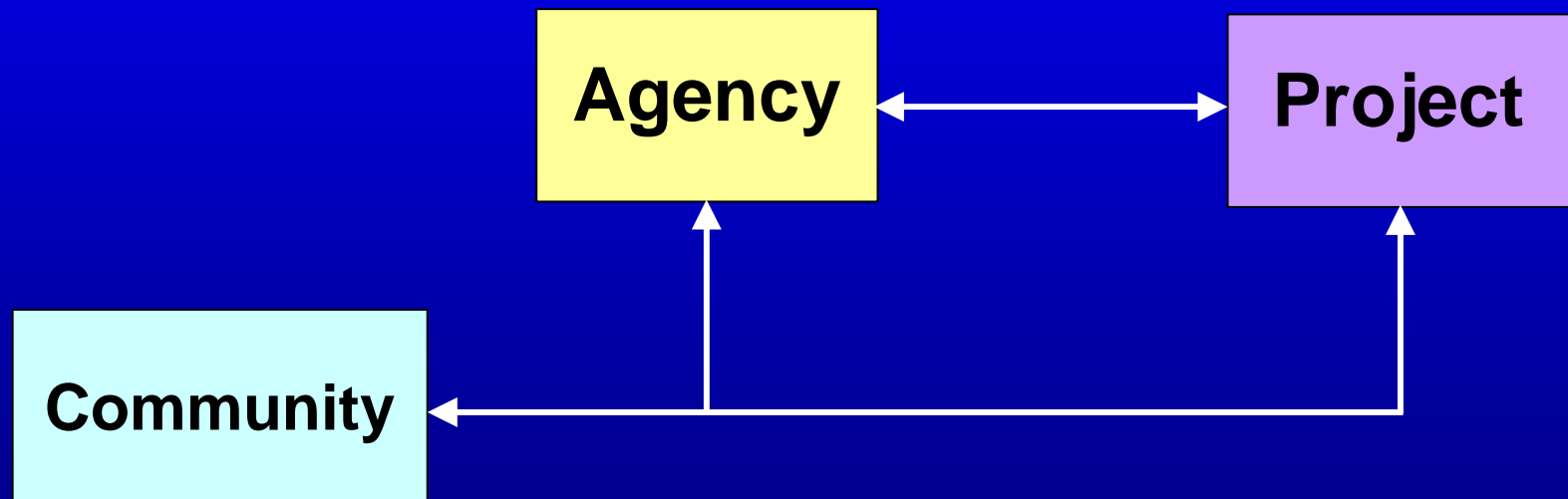
Source: Nance, 2004.

Brazil's Transitions

- ❖ From Authoritarianism to Democracy
- ❖ From Centralization to Decentralization
- ❖ From Conventional to Condominial Sewers
- ❖ From Confrontation to Participation

Many factors affect the performance of sewer projects in Brazil.

Source: Nance, 2004.

Project Delivery Framework

Agency ⟷ Project
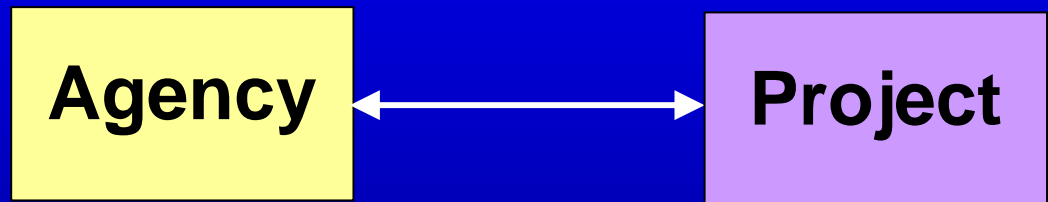
Project Delivery Framework

Source: Adopted from Korten, 1980

# Definitions of Key Terms

- Participation

- Performance

Definition of Participation

The contributions and involvement of residents, households, and the community in a project.

❖ Contributions
  ❖ Construction (labor, materials)
  ❖ Maintenance (labor, materials)

❖ Involvement
  ❖ Mobilizing (meetings, house visits, literature)
  ❖ Decisions (service level, piping layout)

Source: Nance, 2004.

Operationalizing Participation

Source: Nance, 2004.

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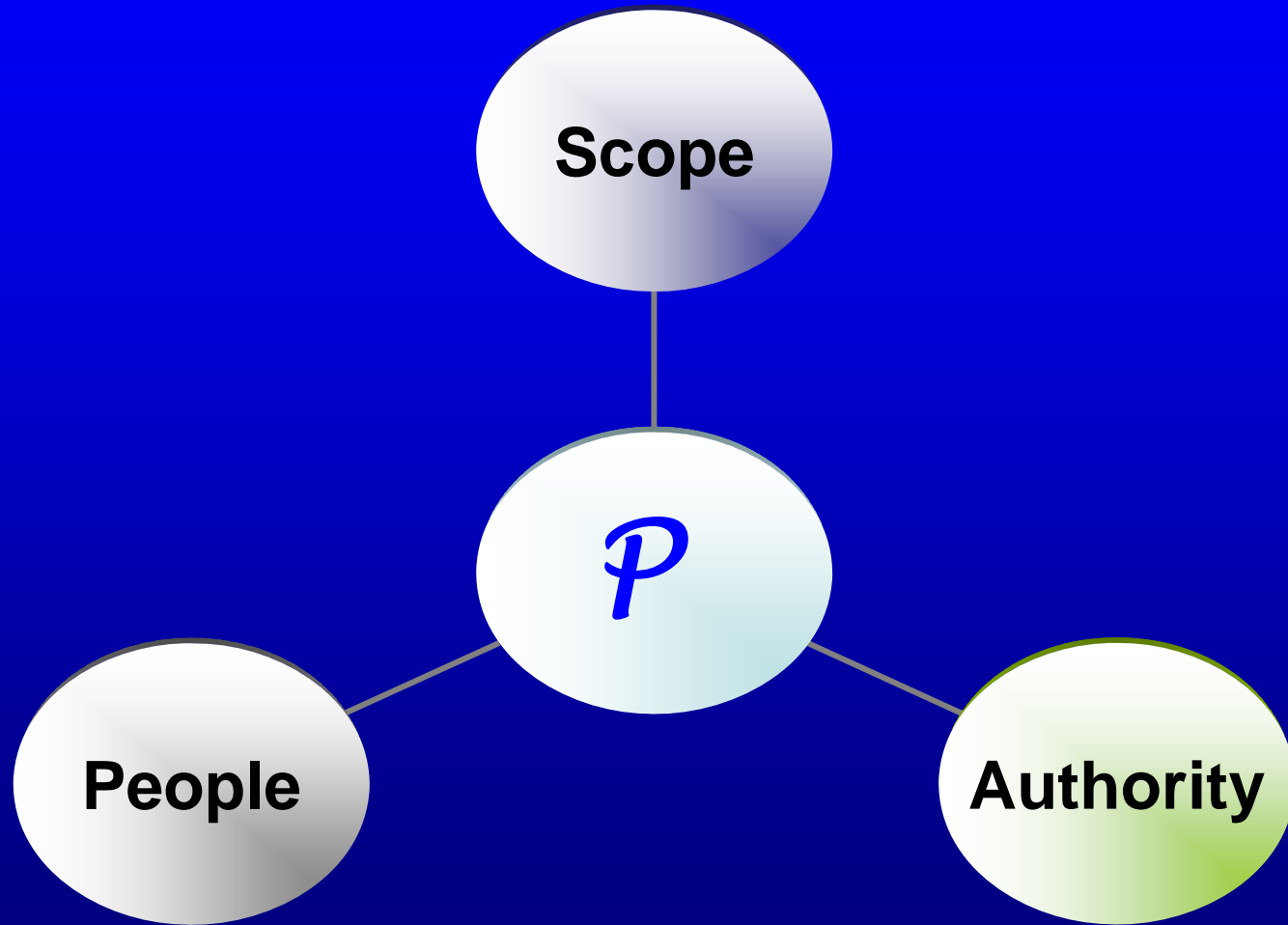
Participation Index

Participation Index $= A \cdot w_a + P \cdot w_p + S \cdot w_s$

Where: A = level of user authority

P = % of residents who participated

S = scope of participation activities
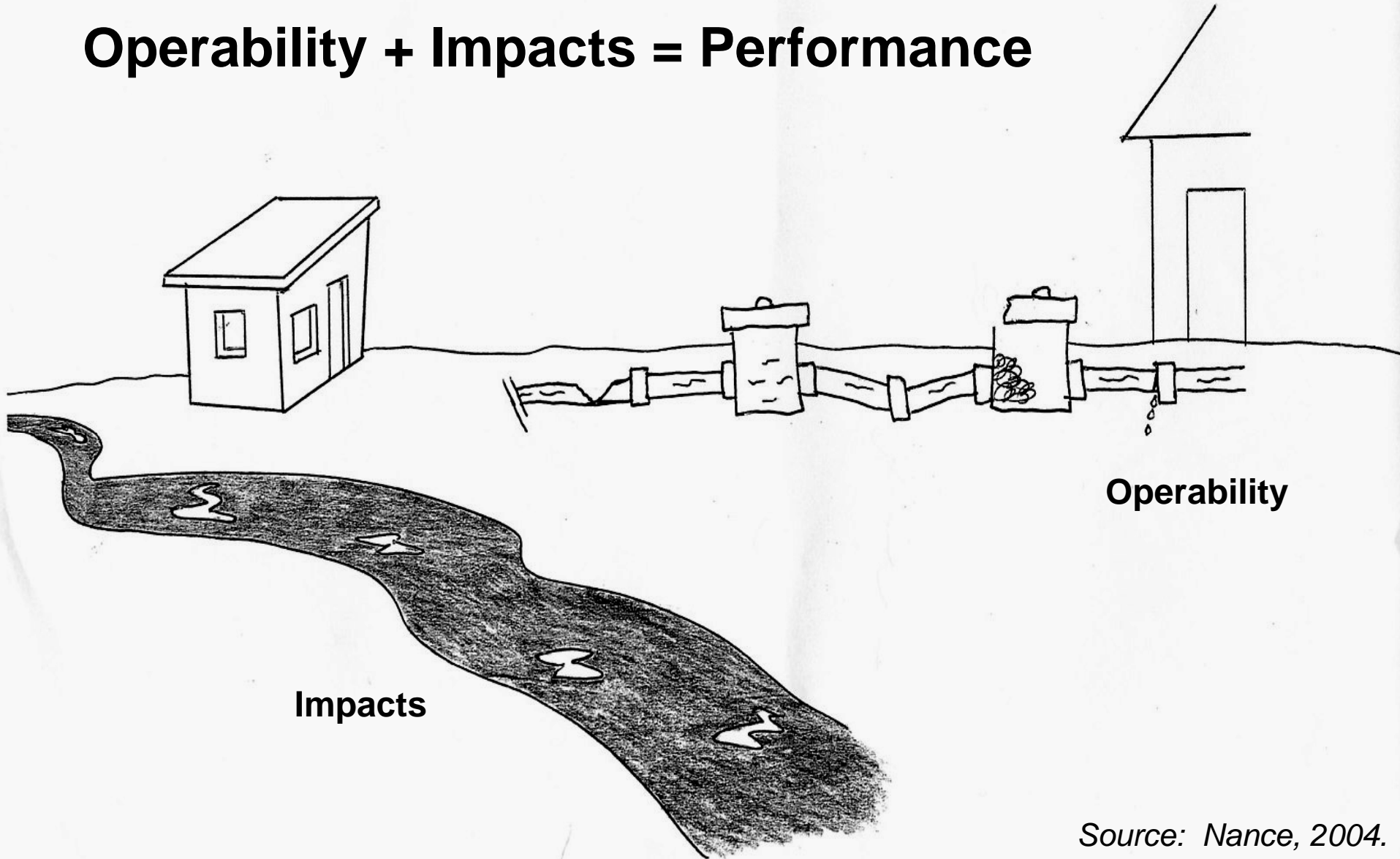
w = weighting factor

$w_a + w_p + w_s = 1$

0 = low participation   (31 indicators)

100 = high participation

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Project Performance

Operability + Impacts = Performance

Operability

Impacts

Source: Nance, 2004.

Performance Index

Performance Index = $I \cdot w_i + O \cdot w_o$

Onde: I = median impact score
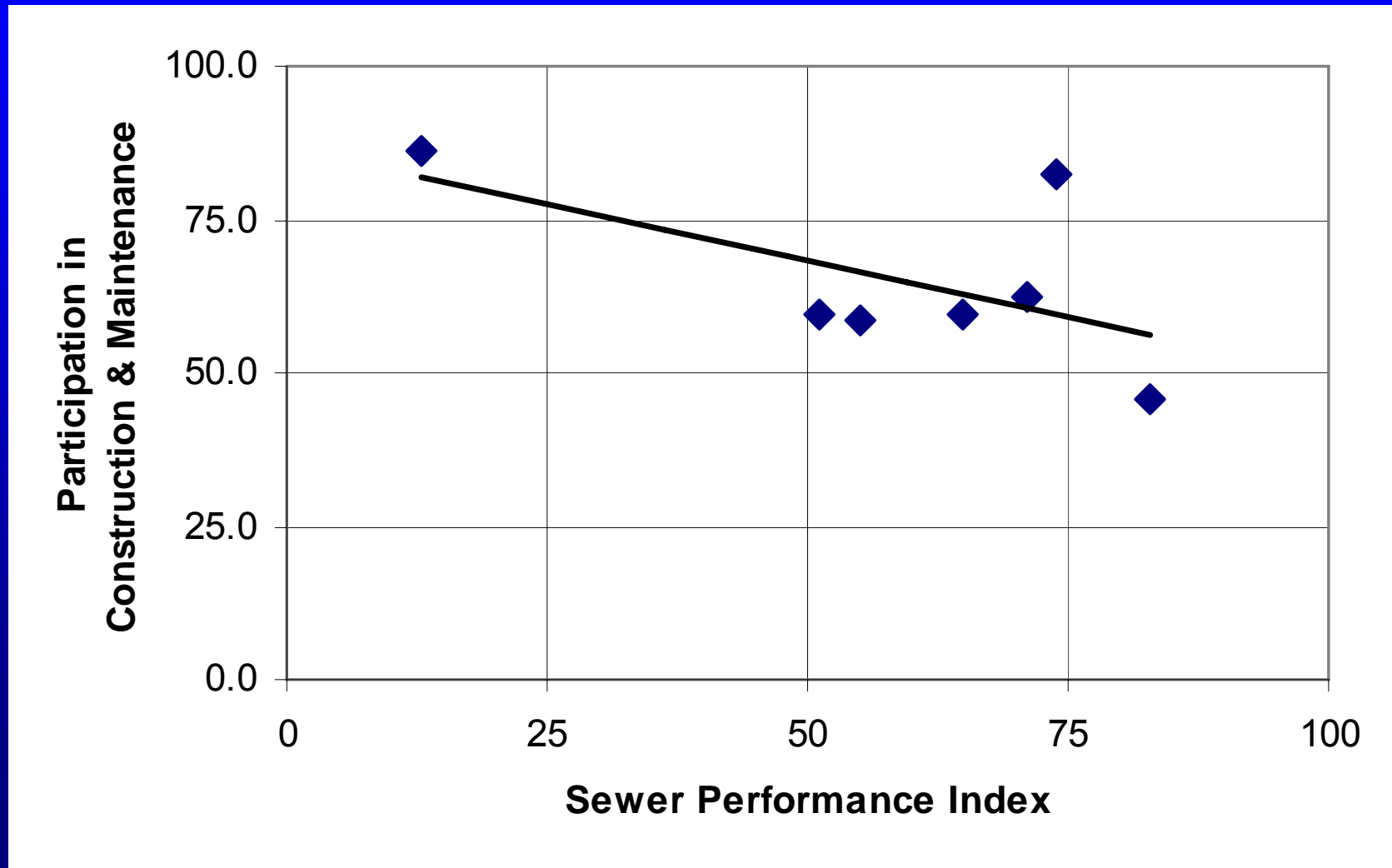
O = median operability score

w = weighting factor

$w_i + w_o = 1$

0 = low performance   (27 indicators)
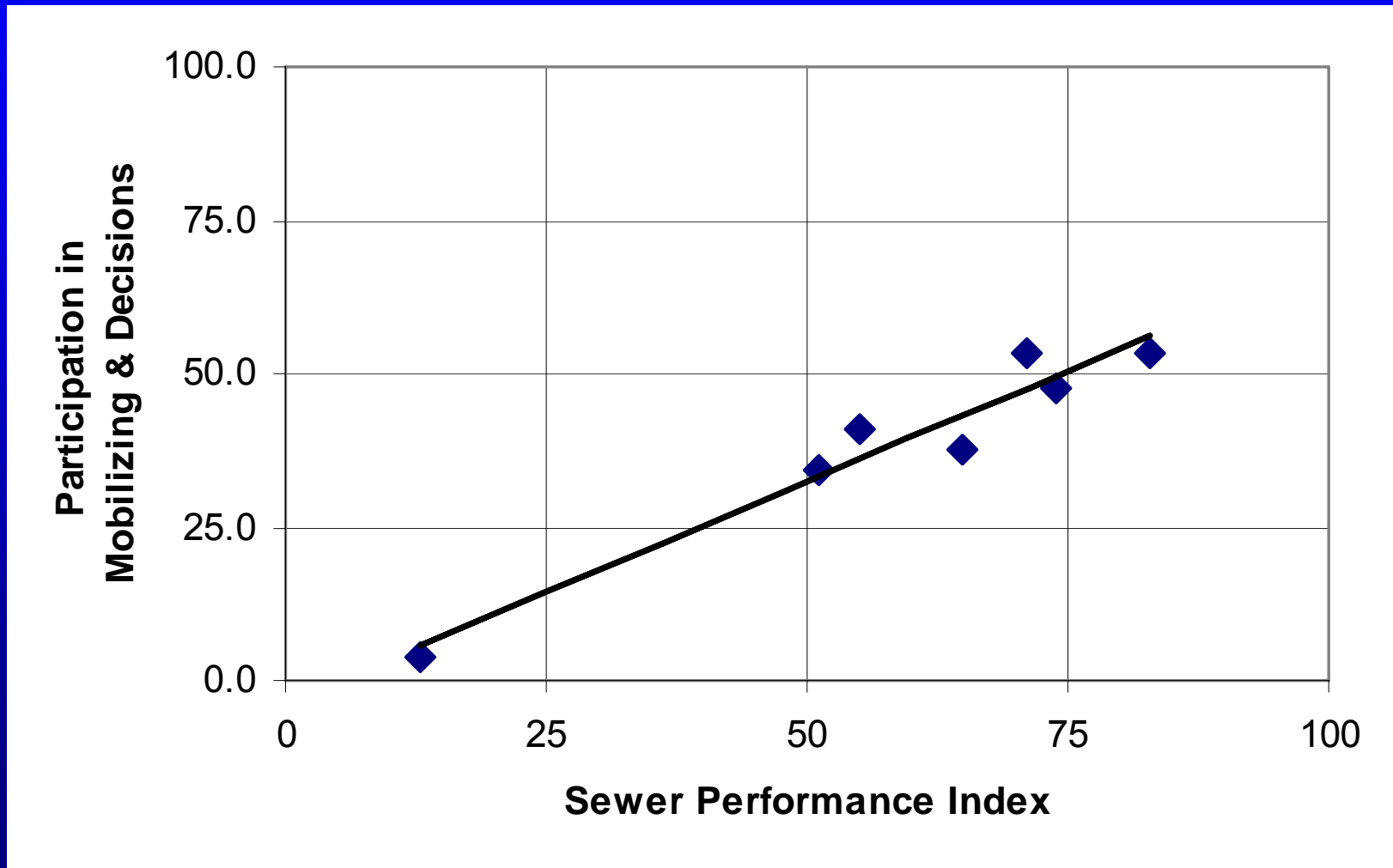
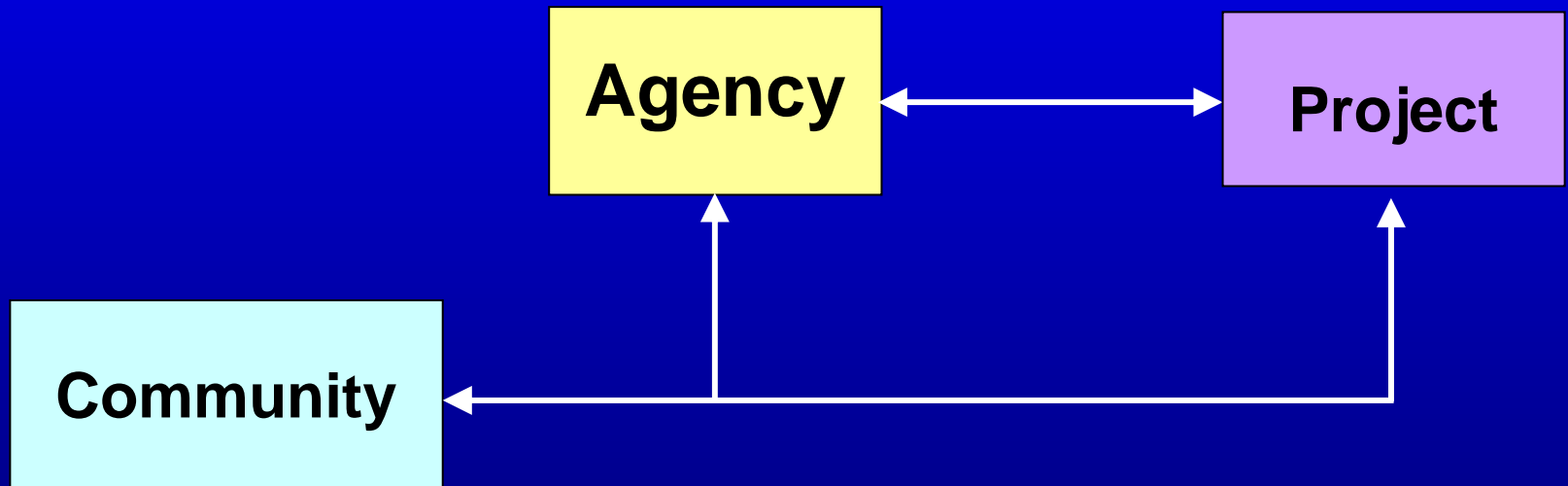100 = high performance

Contributions and Performance

Source: Nance, 2004.

Involvement and Performance

Source: Nance, 2004.

Project Delivery Framework

Agency ⟷ Project

Community

Source: Nance, 2004.

Project Delivery Framework
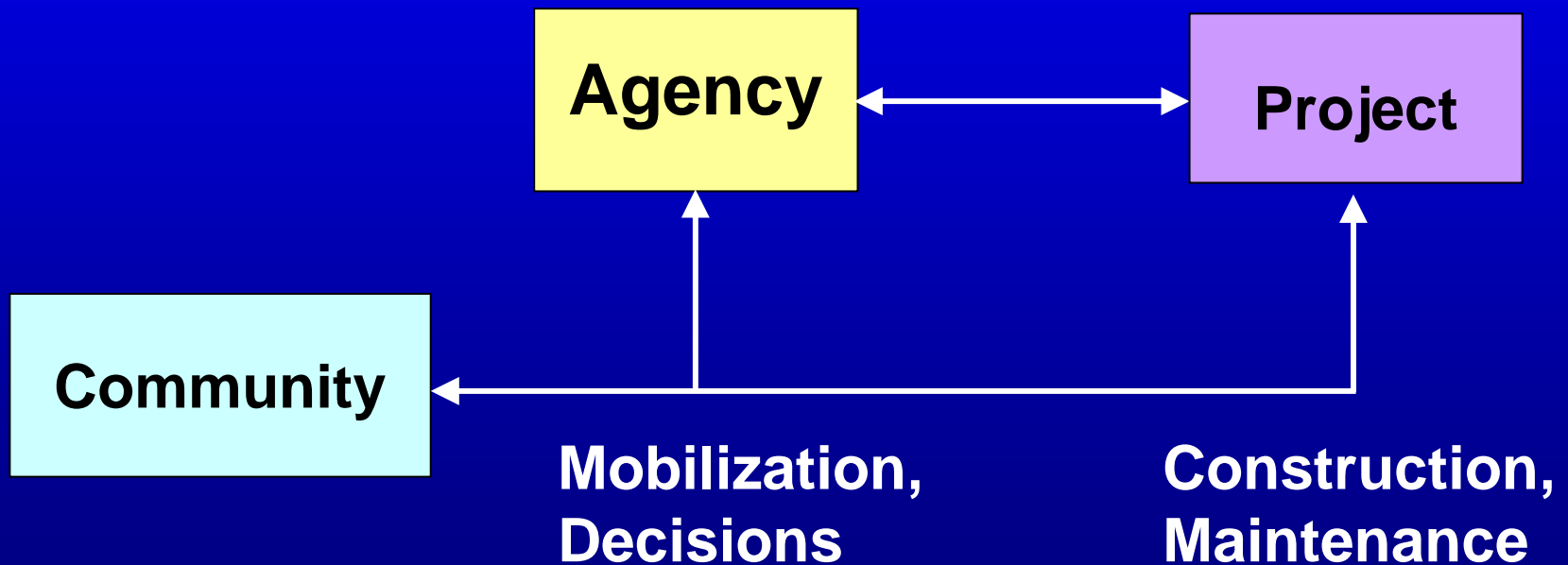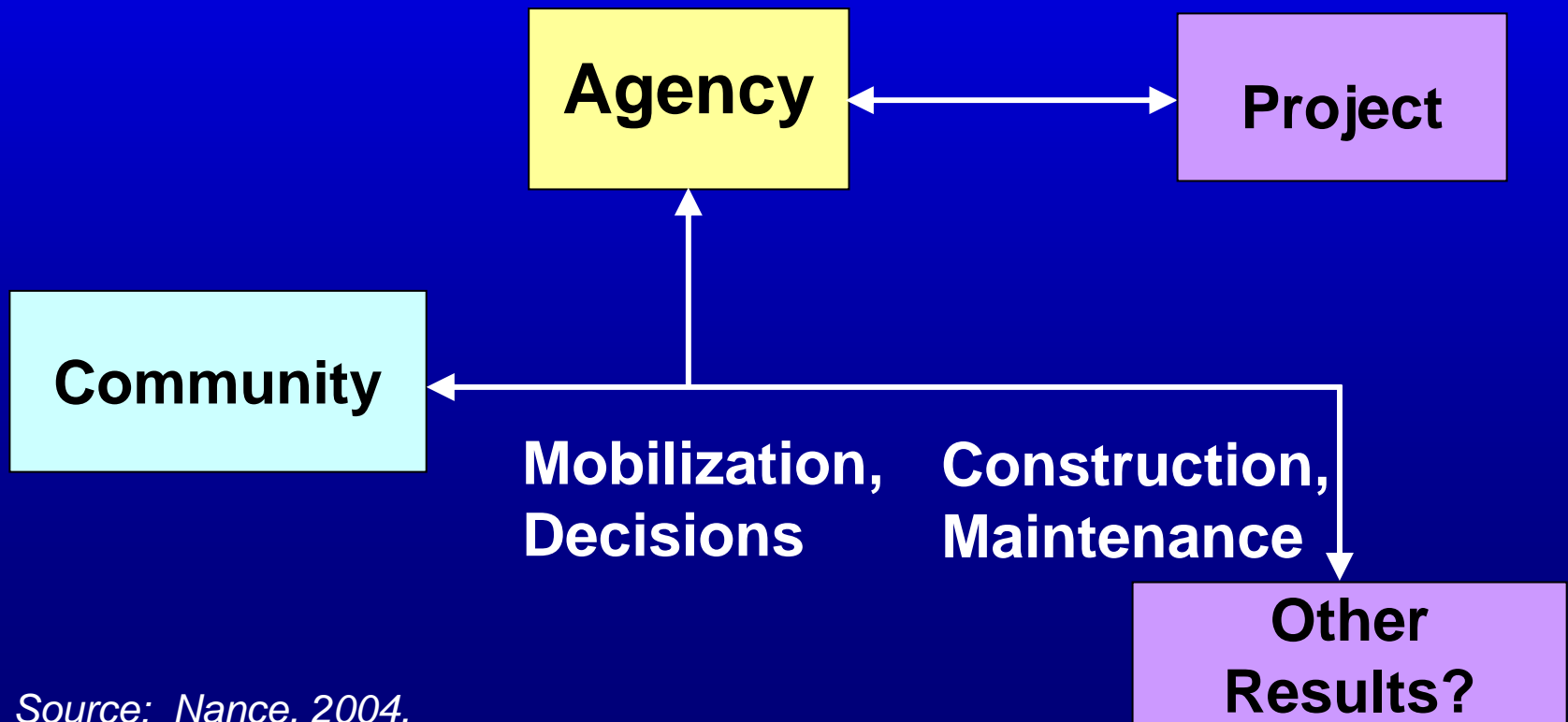
Source: Nance, 2004.

Revised Framework

Agency ⟷ Project

Agency → Community: **Mobilization, Decisions**

Source: Nance, 2004.
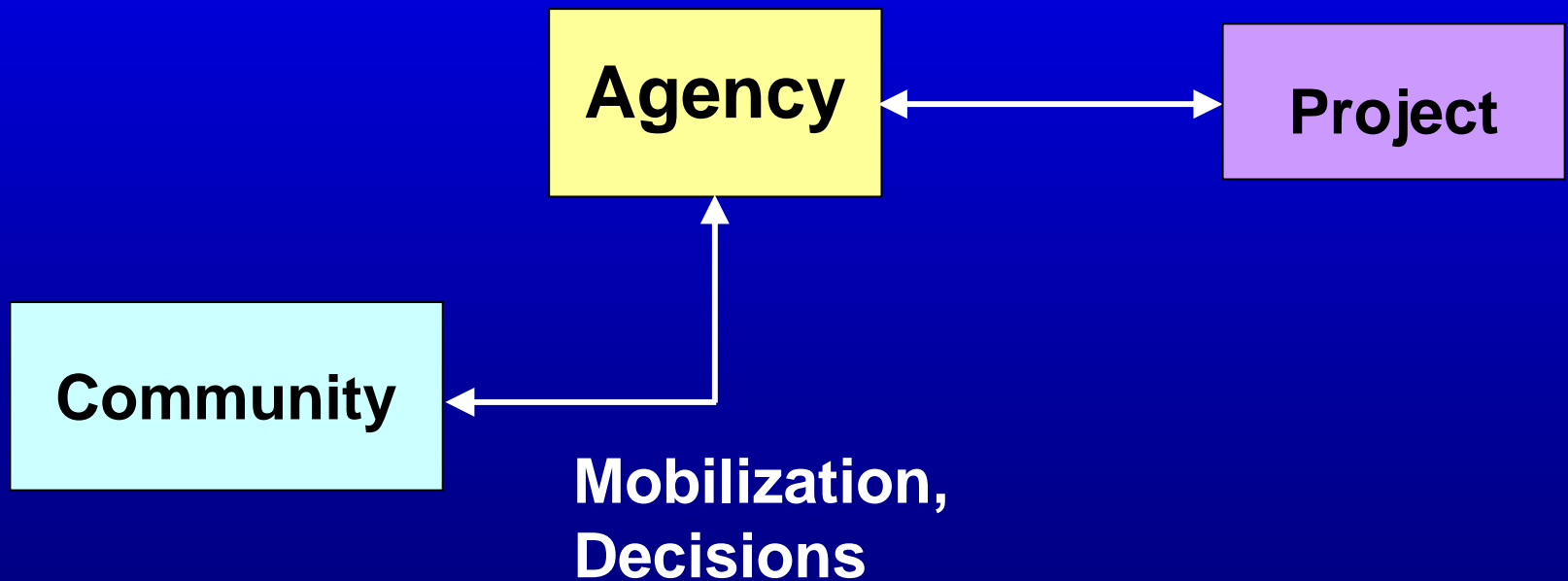
Natal's Context

- Single Implementing Agency
- Continued Dependence on State Agency
- Acceptance of Condominial Technology
- Consistent Participation Program
- Nominal Community Organizing
- Basin-wide Project Focus

Centralized Context

Source: Nance, 2004.

Citywide Performance in Natal

- Citywide performance judged "good" by agency staff (3 on a 1 - 5 scale, 5 staff)

- Citywide performance judged "good" in a World Bank-commissioned study (2 on a 1 - 3 scale)

- Few failed projects

Good Performance

Source: Nance, 2004.

Implementation in Natal

Phase 1 - The Golden Age (1980 - 1990)

Phase 2 - The Intermission (1991 - 1994)

Source: Nance, 2004.

Case N1 (good performance)

- Upper-middle income, small population
- Not organized, no special relationships
- Single state agency
- Supportive, responsive implementing agency
- With participation
- One state regime

Source: Nance, 2004.

Case N2 (good performance)

- Low income, large population
- Not organized, no special relationships
- Single state agency
- Supportive, responsive implementing agency
- With participation
- Two state regimes

Source: Nance, 2004.

Case N3 (good performance)

- Lower-middle income, large population
- Not organized, no special relationships
- Single state agency
- Supportive, responsive implementing agency
- With participation
- Two state regimes

Source: Nance, 2004.

Alignment of Interests

A condition in which politicians and agencies have mutual, shared interests.

Indicators:

1. Responsive to People's Needs
2. Supportive of Appropriate Technology
3. Continuity Between Regimes
4. Cooperation Between Agencies

Source: Nance, 2004.

Alignment of Interests in Natal

Case	Alignment of Interests				
	Supportive	Responsive	Continuity	Cooperation	Overall
N1	✓	✓	✓	✓	Stable
N2	✓	✓		✓	Stable
N3	✓	✓		✓	Stable

Source: Nance, 2004.

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Previous Framework

Agency ⟷ **Project**

Community

Mobilization, Decisions

Source: Nance, 2004.

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Revised Framework

Officials ← Alignment ← Agency

Agency ↔ Project

Agency ↑ Mobilizing, Decisions → Community

Community

Source: Nance, 2004.
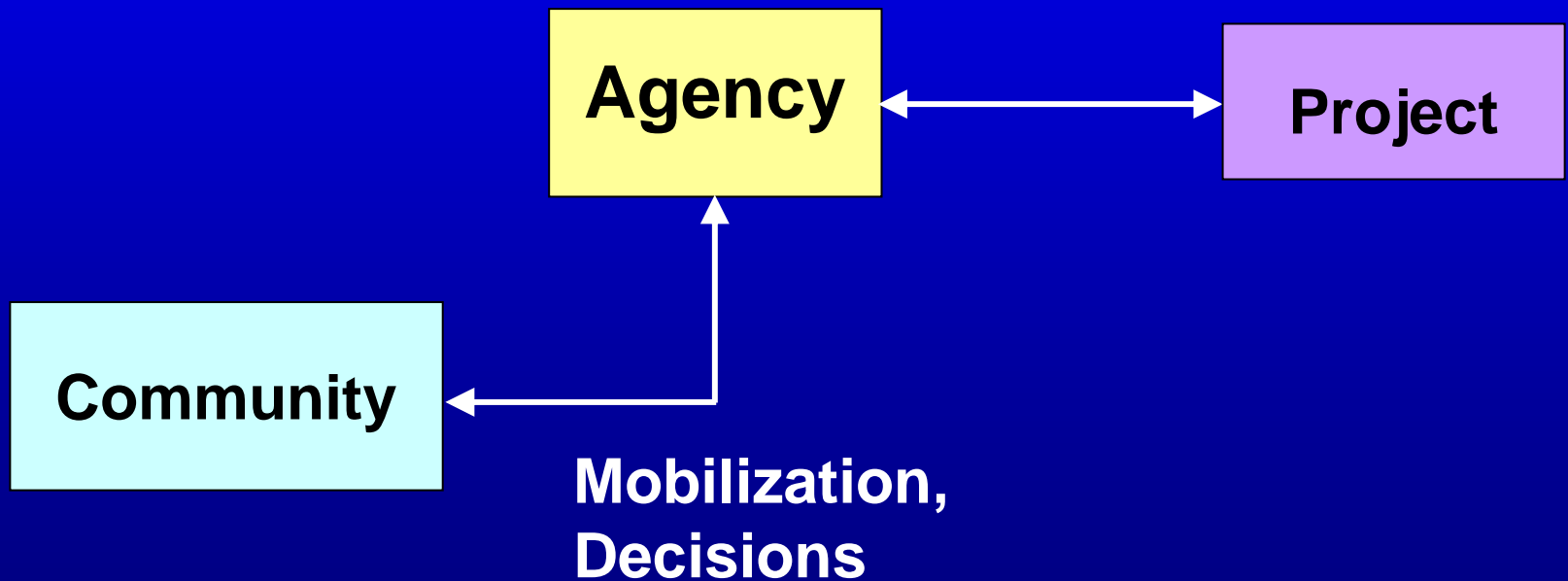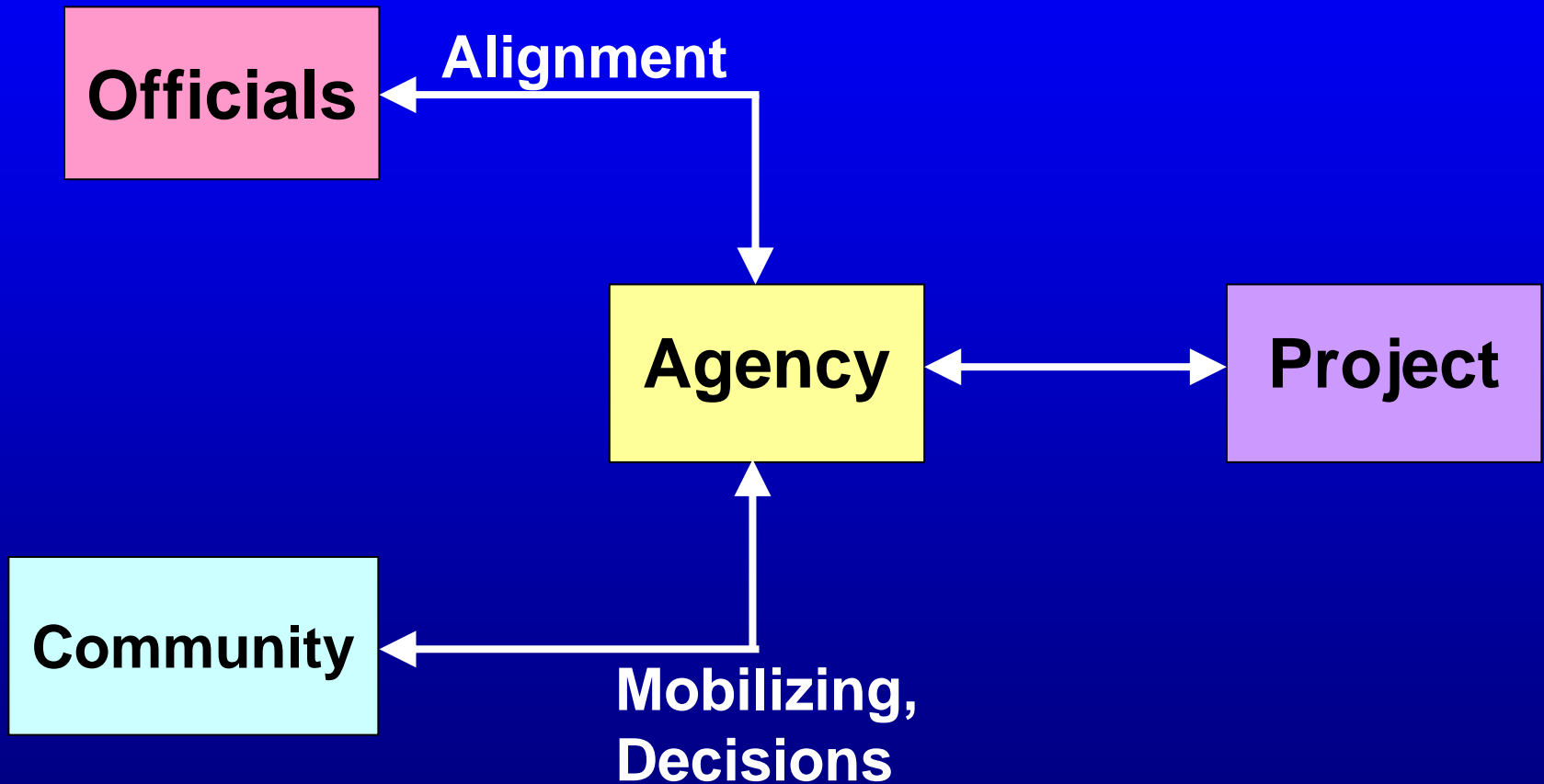
Recife's Context

- Multiple Implementing Agencies
- Expansion of Municipal Capability
- Incomplete Acceptance of the Technology
- Inconsistent Participation
- Significant Community Organizing
- Neighborhood Project Focus

Ad Hoc Context

Source: Nance, 2004.

Citywide Performance in Recife

- Citywide performance judged "fair" by agency staff (2 on a 1 – 5 scale, 8 staff)

- Citywide performance judged "bad" in a World Bank-commissioned study (1 on a 1 – 3 scale)

- Few good projects

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Fair Performance
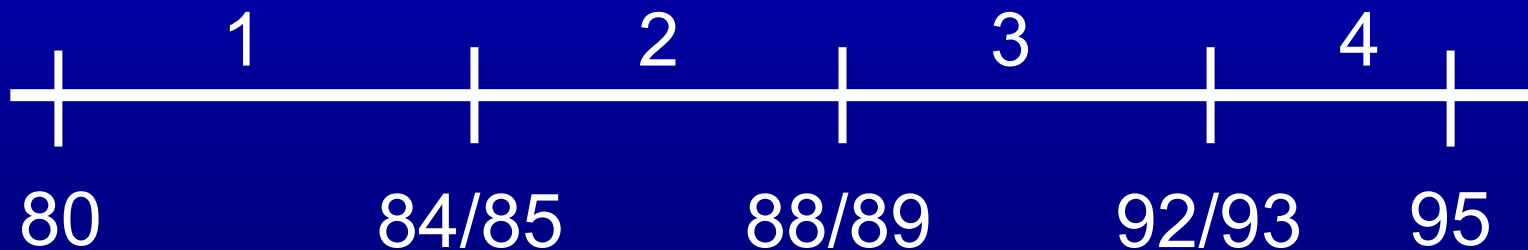
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Source: Nance, 2004.

Implementation in Recife

Phase 1 - Pre-Implementation (1980-84)

Phase 2 - Initiating Participation (1985-88)

Phase 3 - Revisiting Conventional (1989-92)

Phase 4 - Consolidating Participation(1993-95)

Source: Nance, 2004.

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Case R1 (good performance)

- Upper-middle income, small population
- Well organized, special relationships
- Two implementing agencies (city + state)
- Supportive, responsive implementing agencies
- With participation
- One city regime

Source: Nance, 2004.

Case R2 (bad performance)

- Lower-middle income, small population
- Not organized, no special relationships
- Two implementing agencies (city + state)
- Non-supportive, non-responsive agencies
- No participation
- Two city regimes

Source: Nance, 2004.

Case R3 (good performance)

- Low income, large population

- Well organized, special relationships

- Two implementing agencies (state + state)

- Supportive, responsive implementing agencies

- With participation

- One state regime

Source: Nance, 2004.

Alignment of Interests in Recife

Case	Alignment of Interests				
	Supportive	Responsive	Continuity	Cooperation	Overall
R1	✓	✓	✓	✓	**Stable**
R2					**Unstable**
R3	✓	✓	✓	✓	**Stable**

Source: Nance, 2004.

Community Influence

The ability of a community to persuade politicians and agencies to take the community's interests into account.
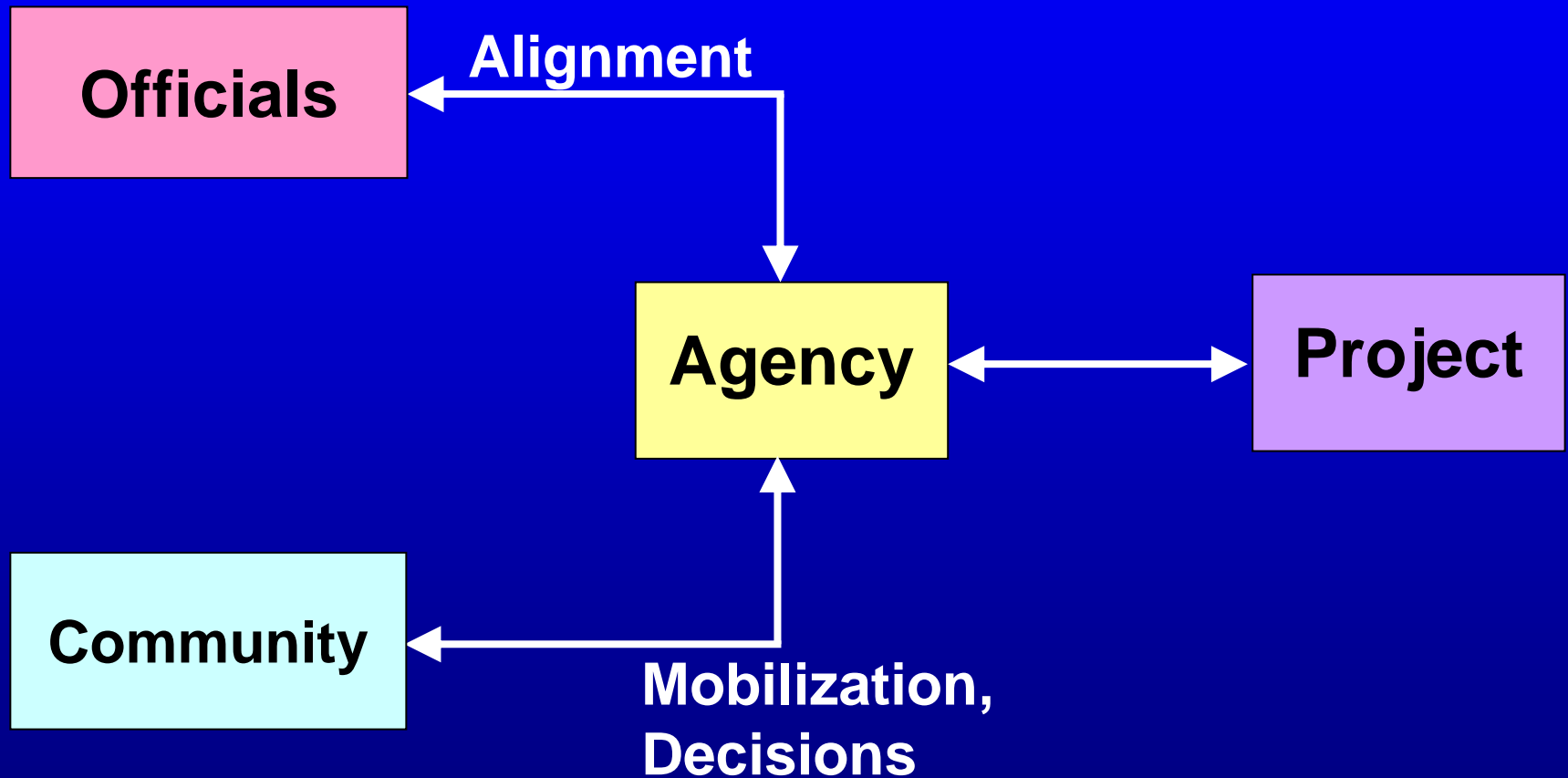
Indicators:

- Population Size
- Socio-Economic Level
- Degree of Organization
- Relationships

Source: Nance, 2004.

Community Influence in Recife

Case	Community Influence				
	High Income	**Large Population**	**Well Organized**	**Relationships**	**Overall**
R1	✓		✓	✓	**High**
R2					**Low**
R3		✓	✓	✓	**High**

Source: Nance, 2004.

Previous Framework

Officials

Alignment

Agency ←→ **Project**

Community

Mobilization, Decisions

Source: Nance, 2004.

Revise the Framework Again
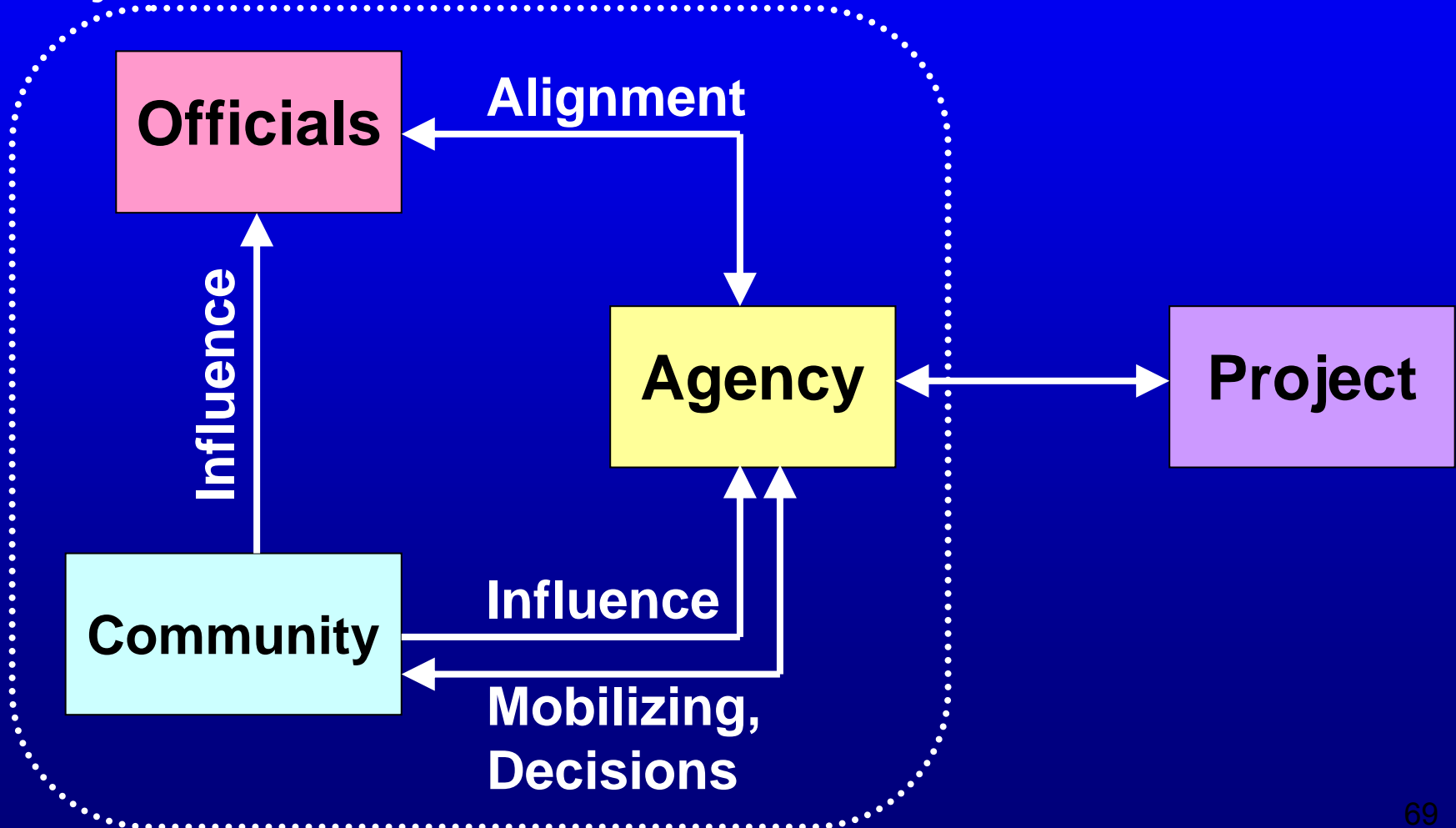

Source: Nance, 2004.
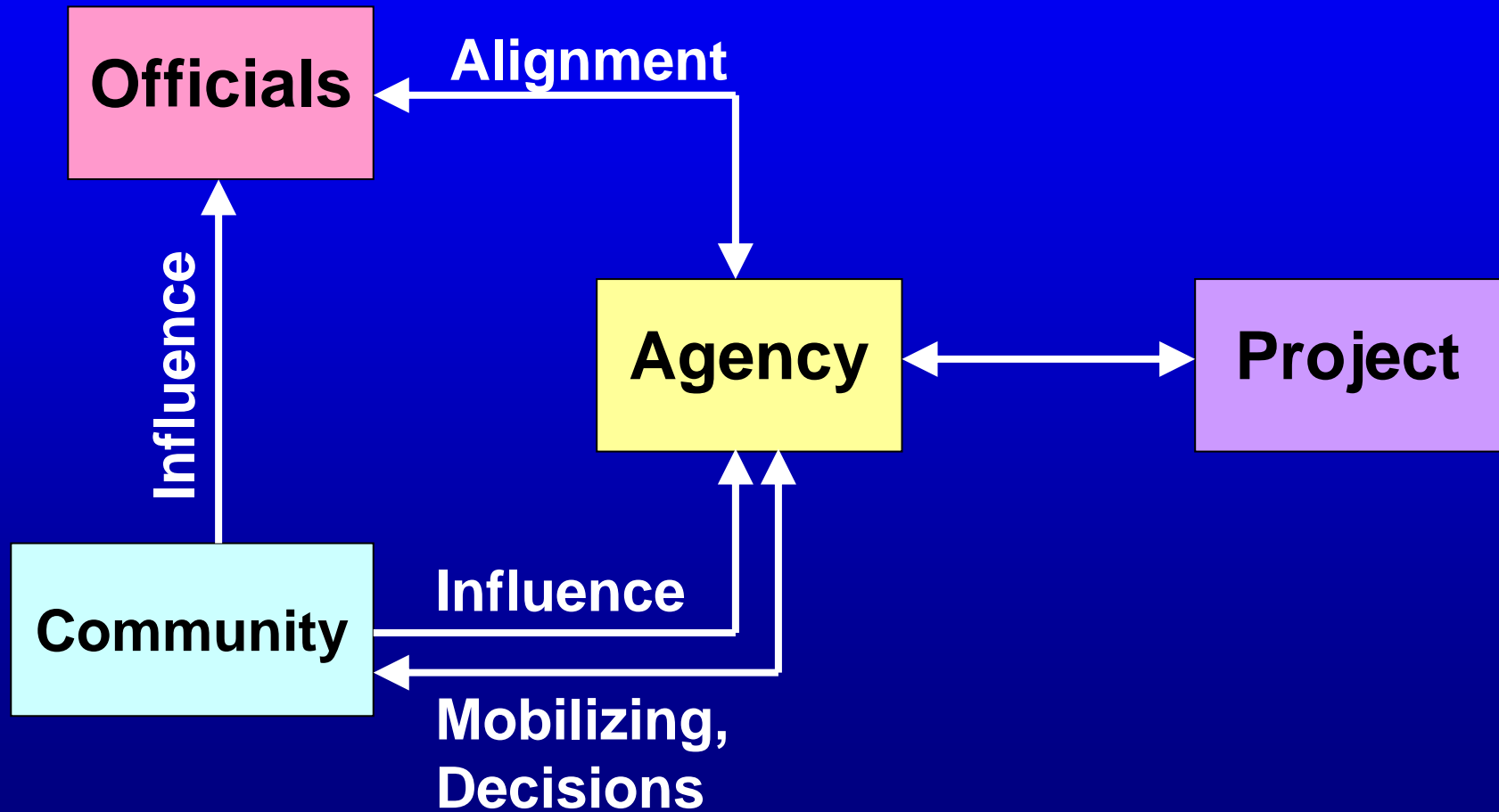
Summary of Recife's Experience ☼

- Fair performance citywide, wide variation

- Two categories of participation varied with performance

- Alignment of interests varied with performance

- Community influence varied with performance

- Add a new dimension to the framework:

Community Influence

Source: Nance, 2004.

Project Coalition Framework

Project Coalition

Officials

Alignment

Agency

Project

Influence

Community

Influence

Mobilizing, Decisions

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Source: Nance, 2004.

Why Did Case R2 Fail?

- **A weak, short-lived project coalition**
  - **Lack of alignment**
  - **No participation in mobilizing/decisions**
  - **No community influence**
- **Project implementation was disrupted**
- **High participation in construction and maintenance was ineffective**
- **Project coalition was weak and was not maintained**
- **Project was eventually abandoned**

Source: Nance, 2004.

Why Did Case R3 Succeed?

- **A strong, stable project coalition**
  - **Alignment**
  - **Participation in mobilizing/decisions**
  - **Community influence**
- **Project coalition was maintained**
- **Monthly visits to the sewer agency**
- **Organized votes at each election**

Source: Nance, 2004.

Why Did Natal Perform Better?

- **Natal's centralized service provision context enabled strong, stable project coalitions to form more frequently**

- **Recife's ad hoc service provision context made it more difficult for strong, stable project coalitions to form**

Source: Nance, 2004.

Research Question

What factors enable good performance

in condominial sewer projects?

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Conclusions

Project performance was contingent on the strength and stability of the project coalition.

a. Project coalitions were comprised of officials, agencies, communities.

b. Project coalitions were strong and stable when interests were aligned, when communities had influence, and when communities participated in project mobilizing and decisions.

Source: Nance, 2004.

References

Nance, Earthea B. and Leonard Ortolano. 2006. "Community Participation in Urban Sanitation: Experiences in Northeastern Brazil," *Journal of Planning and Education Research (in press).*

Nance, Earthea B. 2005. "Multi-Stakeholder Evaluation of Condominial Sewer Services," *American Journal of Evaluation 26(4):480-500.*

Nance, Earthea B. May 2004. "Putting Participation in Context: An Evaluation of Urban Sanitation in Brazil." Ph.D. dissertation, Stanford University.

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