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THE IMPACT OF WATER AVAILABILITY ON FOOD SECURITY

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“Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life”

(World Food Conference, 1996)

Global SCs are increasingly experiencing resource constraints

Examples:

1) Ground water over pumping

Companies affected: Coca-Cola (India)[1], Pepsi Co[2], Nestle – Perrier (Brazil)[3,4]

2) *Severe drought*

Companies affected: Anheuser-Busch (US)[6], Solvay (pharmaceuticals, Brazil)[7], Alta Mogiana (sugar processing company, Brazil)[8], Miller Coors (Beverage sector, US)[9]

3) *Water quality*

Companies affected: Rice fields in Guangzhou[12,13]

Consequences: All the companies were forced to change their supply chain structures or even stop their operation in the area

The aim of the research

To advance understanding of causal relationships between local resource availability and the demand side impacts of supplying geographically dispersed markets (example of Food SCs)

Resource availability: Water

Natural capital theory (NCT) emphasises the depletable nature of resources and the effects pollution and ecosystem change have on the environment (Faucheux et al. 1997) as a result of environmentally disruptive economic activities.

This, in turn creates irreversible ruptures between short-run performance and long-run prospects for economic output (Faucheux et al. 1997)

Current research adapts the NCT perspective on natural resource availability to be used for subsequent SC reconfiguration analysis.

Resource availability in current research is defined by a combination of:

- Natural resource supply
- Resource demand (local and global)
- External environmental factors

Water supply

- The amount of water available for utilisation varies on the geographical features of a region
- Water scarcity emerges when there is “an imbalance of supply and demand under prevailing institutional arrangements and/or prices (FAO 2013a, 5)
- Falkenmark et al. (1989) present a water stress index based on estimated water requirements for the household and agricultural sectors, the population of an area, and annual water availability
- The index devised by Falkenmark et al., however, does not take into account various factors - sectorial industrial water usage, consumer use (based on the level of income), water quality, external factors (climatic conditions), and levels of urbanisation and industrialisation – which also have an impact on water availability

Water supply

Levels of water scarcity by Falkenmark et al. (1989)

Annual Renewability of Freshwater (m^3 /person/ year)	Level of Water Stress
< 500	Absolute water scarcity
500-1000	Chronic water shortage
1000-1700	Regular water stress
1700	Occasional or local water stress

Water supply

- Water availability can be influenced by **the quality of water.**

Water quality is defined by its suitability for use (Ayes and Westcote 1976)

a) Water may contain hazardous dissolved substances including cadmium, chloride, chromium, cyanide, nitrite, sodium, and plasticizers (USGS 2014)

b) The implementation of harmful pesticides, fertilisers in agriculture, or inadequate wastewater treatment will frequently result in water contamination (FAO 2012)

Water demand

Water demand is characterised as the water footprint of a nation or a particular region - the total volume of freshwater required to produce goods or services that are consumed by the population of the region (Chapagain et al. 2006)

- Industrialisation significantly influences the availability of water in a particular location due to the intensive concentration of the number of industries in the location and the level of water demand required for their production operations.
- Urbanization facilitates intensification of water use and deterioration of water quality (Postel 2000; Feldman 2012; Brown and Halwei 1998)

	Water use (litter/capita/day)		
Region	Average	Minimum	Maximum
Developed countries – reported or measured	307	130	578
Newly industrialized countries – reported or measured	199	86	366
Developing countries – reported or measured	44	4	400
African countries – reported or measured	31	5	100
Communities in Central& South America - metered	67	25	133
WHO Standard	50	20	100

Table 1. Water requirements (Adapted from Davis 2014)

Industry		Materials	Suppliers	Direct	Product use
Food and beverage	Withdrawal	High	Medium	High	Medium
	Discharge	Medium	Low (medium for food)	Medium (high for food)	Medium
Semiconductor	Withdrawal	High	High	Low/medium	Low
	Discharge	Medium	High	Low	Medium
Power	Withdrawal	High	Low	High	N/a
	Discharge	High	Low	High	N/a
Extractive	Withdrawal	High	Low	High	Medium
	Discharge	High	Low	High	Medium
Manufacturing	Withdrawal	Low to medium	Low to medium	Low to high	Low to high
	Discharge	Low to medium	Low to medium	Low to high	Low to high

Table 2. Water footprint by industry sector (Adapted from Sarni 2011)

External factors

1) Climate change is “expected to account for about 20 per cent of the global increase in water scarcity” (FAO 2007, 15). Changes in climate result in increased droughts, heat waves, glacial melting, early springs, early vegetation, increased evapo-transpiration, changing vegetation cover, rising water levels due to an increase in global sea levels and prolonged rain seasons, etc.
2) Extreme weather events have a direct influence on the increased frequency of droughts, floods, heat waves, heavy rainfall, storms, and tropical cyclones (IPCC, 2012). At the World Economic Forum (2012) extreme weather events were ranked as the second most significant supply chain disruptor (Bhatia et al. 2013)
3) El Niño and La Niña have potentially catastrophic impacts on water availability. The nature of these events is a result of extreme changes in air pressure (National Geographic 2015a). Heavy rainfall, costal flooding, erosion, droughts, hurricanes, monsoons, and typhoons are caused by these events

Food SC configuration

- The concept of supply chain configuration was built upon strategic management theory to help align the company's organisational structure with its operational environment (Meyer et al. 1993; Miller 1986; Chandra et al. 2007; Srai and Gregory, 2008)

- SC reconfiguration presents the ability to adjust SC structure with environmental constraints in such a way as to allow SC and the environment to "symbiotically coexist" (Beamon 1999, p.336)

- Food SC design and redesign is based on product attributes, therefore manufacturing processes for fresh produce and processed food are organised differently with main focus on traceability

- Analysis of Food SC reconfiguration parameters can help in responding to increasing pressure due to resource scarcity

Food SC configuration

- Product-centric SC configuration theories identifies multiple SC configuration attributes to be considered in supply network design e.g. Srai and Gregory (2008) four dimensions model:

a) Supply network structure

b) Product value structure

c) SC process flow

d) SC governance structure and coordination mechanisms

Food SC configuration responding local water stress: Supply network structure

- Tier structure comprises of a number of network tiers involved in the production process, including: supplier tier(s) (raw materials suppliers, secondary suppliers, and direct suppliers), manufacturing tier (pre-processing, assembly, final assembly, and finishing), distributor tier (warehouses, distribution centers, and cross-docking points), retailer tier(s) (wholesalers, retailers, and brokers), customer tier(s) (B2B and B2C) (Chandra and Grabis 2007; Lambert 2008; Wisner 2011; Bhadada 2013)

- Local supply base analysis of the suppliers, which can be potentially affected by water shortage

- The level of geographical dispersion: a number of sites in geographical area

Food SC configuration responding local water stress: Product value structure

Traceability of the product components in FSC is essential, especially in resource constrained environment

A particular attention should be paid:

- Product resource (e.g. water) intensity (Roth et al. 2008)
- Product resource quality requirements
- Product waste generation management provides opportunity to maximise yields and mitigates potential risks of water shortage and environmental degradation (Beamon 1999)

Food SC configuration responding local water stress: Process flow structure

- Analysis of resource intensity in SC production/assembly operational processes
- Focus on resource quality for the food and beverage production processes in particular
- Consideration of waste recycling for minimization of the harmful effects of production processes on natural environment (Beamon, 1999; Golinska et al. 2007)

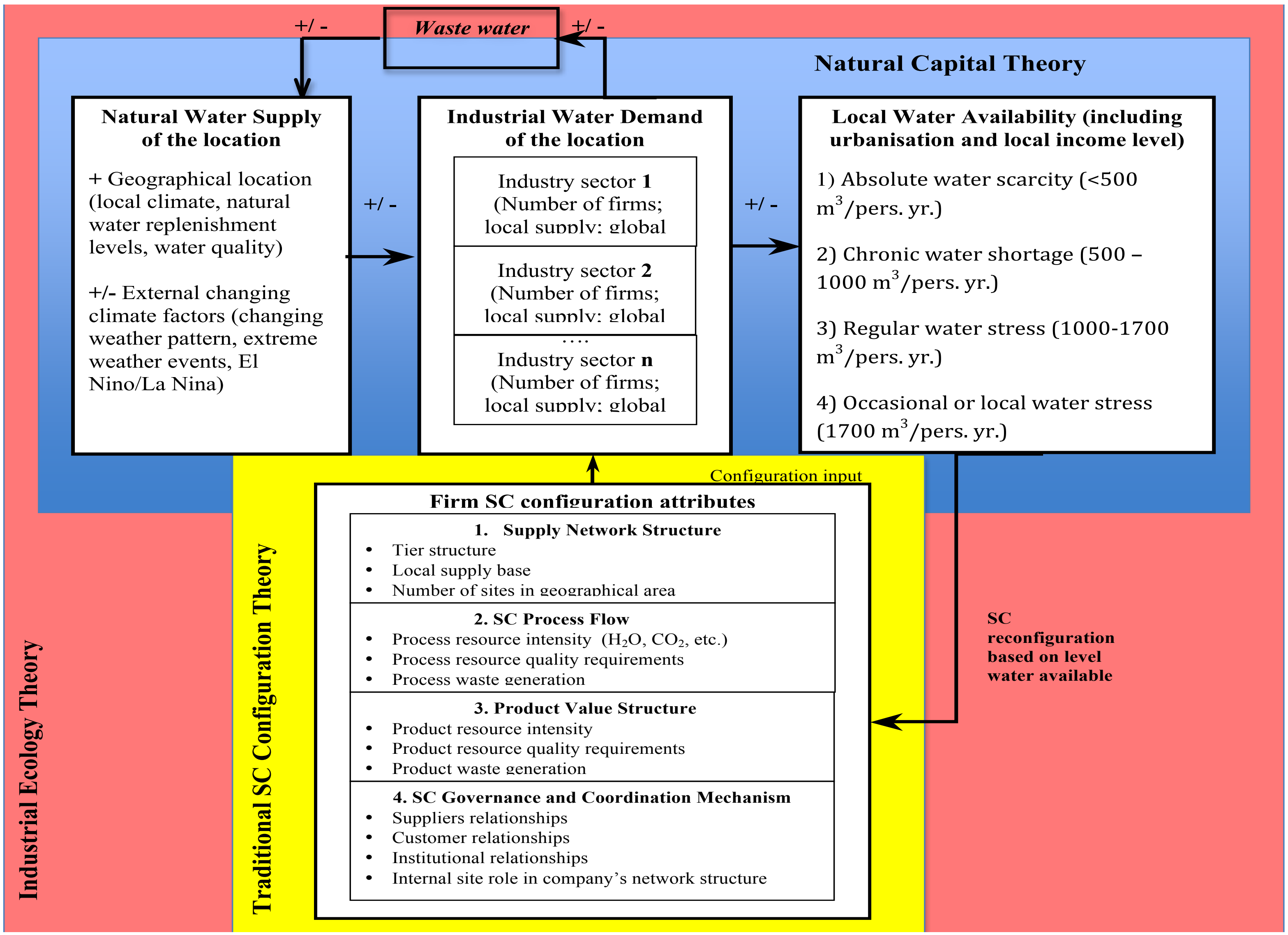
Food SC configuration responding local water stress: FSC Governance structure and coordination mechanisms

- Suppliers relationships are important for reducing of cost, time, and uncertainty (e.g. resource scarcity)

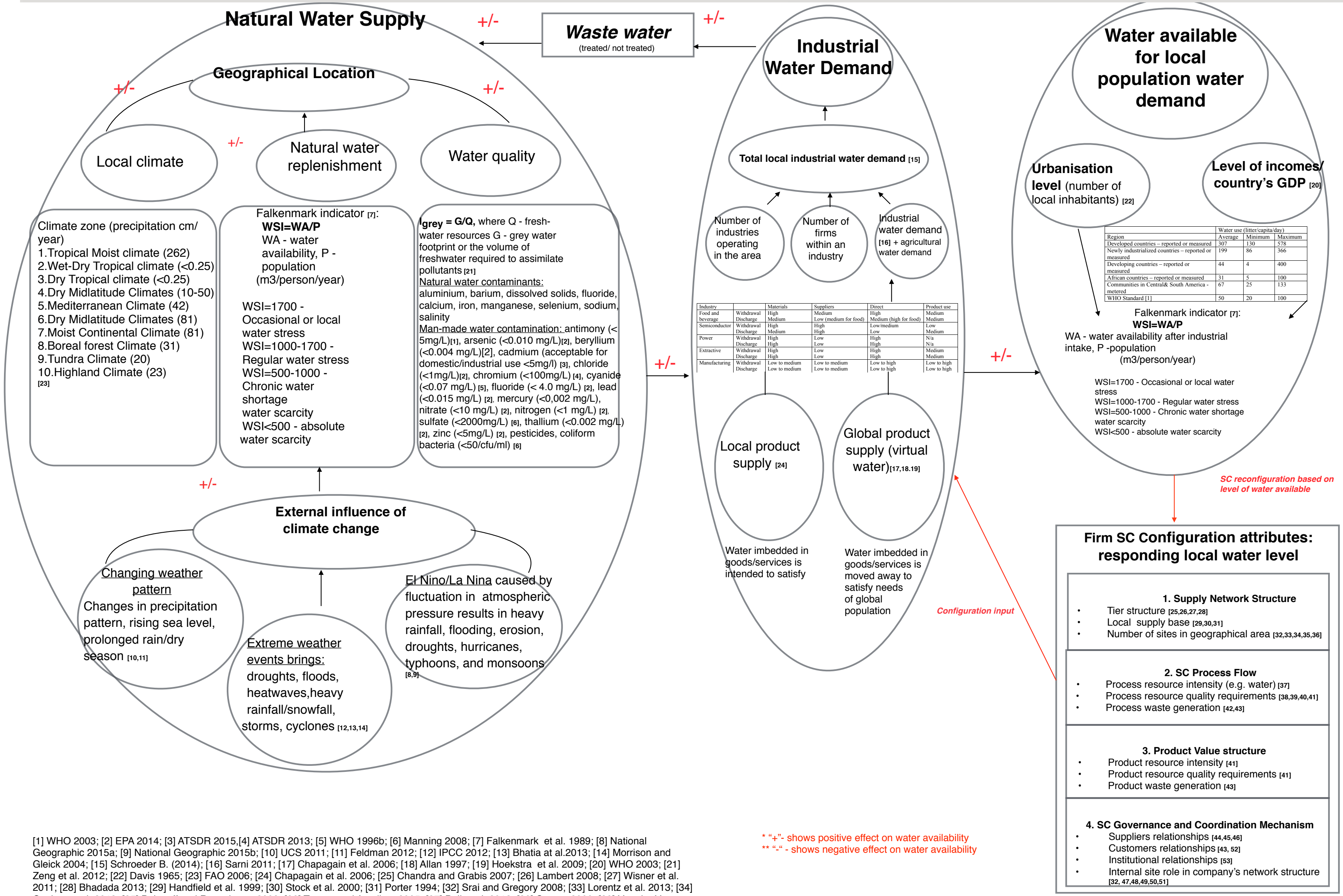
- Customer and Institutional relationships are also important to maintain. As water stress locations are becoming a subject of concern for stakeholders (institutional authorities and customers) (Sodhi and Yatskovskaya 2014) company's reputation becomes extremely vulnerable to resource availability patterns on certain locations (Beamon 1999; Cox et al. 2003)

- Internal position of the site in the company's network structure determines potential economic output, including: control over assets, the standardization of operations processes involved, and the facilities available (Barrat 2002; Cooper et al. 1997; Croom et al. 2000)

Water availability assessment framework for SC configuration through theoretical lenses



Water availability assessment framework for SC configuration



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[1] WHO 2003; [2] EPA 2014; [3] ATSDR 2015,[4] ATSDR 2013; [5] WHO 1996b; [6] Manning 2008; [7] Falkenmark et al. 1989; [8] National Geographic 2015a; [9] National Geographic 2015b; [10] UCS 2011; [11] Feldman 2012; [12] IPCC 2012; [13] Bhatia at al.2013; [14] Morrison and Gleick 2004; [15] Schroeder B. (2014); [16] Sarni 2011; [17] Chapagain et al. 2006; [18] Allan 1997; [19] Hoekstra et al. 2009; [20] WHO 2003; [21] Zeng et al. 2012; [22] Davis 1965; [23] FAO 2006; [24] Chapagain et al. 2006; [25] Chandra and Grabis 2007; [26] Lambert 2008; [27] Wisner et al. 2011; [28] Bhadada 2013; [29] Handfield et al. 1999; [30] Stock et al. 2000; [31] Porter 1994; [32] Srai and Gregory 2008; [33] Lorentz et al. 2013; [34] Caniato et al. 2013; [35] Bolstorff and Rosenbaum 2003; [36] Truong and Azadivar 2005; [37] Bell et al. 2012; [38] Soman 2008; [39] Van der Vorst 2000; [41] Manivaskam 2011; [42] Roth et al. 2008; [43] Golinska et al. 2007; [44] Beamon 1999; [45] Frohlich and Westbrook 2001; [46] Handfield, and Nichols Jr. 2002; [47] Holweg, et al. 2005; [48] Barratt 2002; [49] Cooper et al. 1997; [50] Croom et al. 2000; [51] Gereffi at al. 2005; [52] Waters

Coca-Cola case study

- The study is based on a widely reported historical case of Coca-Cola in Plachimada (India) during the period 1999-2006 (HCC BPL 2002)
- Data was obtained through secondary sources, including primary data case studies (Hills and Welford 2005; etc), reports from the government of India (Jayakumar 2010), Plachimada Supreme court acts (Koonan 2007), and news sources (IRC 2008; RIM 2007; FFFM 2009)
- Three time series shows resource availability before the Coca-Cola plant allocation, during plant operation, and after Coca-Cola left Plachimada
- Water table depletion and significant water level deterioration at location was primarily caused by a combination of local (changes in climate, high population density, deteriorating water quantity) and global factors (increased SC dispersion and global demand)
- State's government was forced to close down the plant and the company chose to reconfigure its supply chain by relocating it's bottling operations from Plachimada to Orissa (The Economist Times 2007)

Coca-Cola case study

Parameters	1999 – before Coca-Cola	2003 - during Coca-Cola operating	After 2006 - Coca-Cola left
1) Plachimada natural water supply			
a) Climate zone	Wet-dry tropical climate Average water availability: 3.105 million m^3/year	Wet-dry tropical climate Average water availability: **3.105 million** m^3/year	Wet-dry tropical climate Average water availability: 3.105 million m^3/year
b) Natural water availability	Classified as arable land Water table: 0.65 m	Classified as drought affected area Water table 8 - 13m	Classified as drought affected area Water table start to recover 5-7m
c) Water quality	Acceptable	Contamination with: cadmium (0.02 mg/l), lead (0.065 mg/l)	(2007) Contamination with: cadmium (0.007 mg/l), lead (0.142 mg/l)
d) External influence of climate change	Drought prone area Rainfall 3140 mm/year	Rainfall 1337 mm/year	Rainfall 1835 mm/year
2) Plachimada industrial water demand			
a) Number of industries operating in Plachimada	Agricultural Industry Other industries: N/A	Agricultural Industry Beverage Industry Other industries: N/A	Agricultural Industry - reduced Other industries: N/A
b) Number of operation sites with in an industry		Other industries: N/A Coca-Cola: 1 bottling plant	Other industries: N/A
c) Site's water demand	Agriculture: 2.61 million m^3/year	Agriculture: **2.61 million m^3/year – BDL due to poor water quality** Other industries: N/A Coca-Cola: **0.1825 million m^3/year**	Agriculture: 2.61 million m^3/year- BDL due to poor water quality Other industries: N/A
d) Global water supply vs. Local water supply	Agriculture: N/A	Agriculture: N/A Other industries: N/A Coca-Cola: Regional supply	Agriculture: N/A Other industries: N/A
e) Waste water generation	Agriculture: N/A	Agriculture: N/A Other industries: N/A Coca-Cola: 0.05475 – 0.1095 million m^3/year	Agriculture: N/A Other industries: N/A
3) Water available for population demand in Plachimada			
a) Number of inhabitants	(2001) 54 235 people	N/A	N/A
b) Water requirements	0.9268 million m^3/year	**0.9268 million m^3/year - BDL due to poor water quality**	0.9268 million m^3/year- BDL due to poor water quality
4) Firm SC Configuration attributes of Coca-Cola SC			
a) Supply network structure		Regional plant	Moved the plant to Orissa
b) SC process flow		Water intensive bottling operations	
c) Product value structure		Water and waste intensive product	
d) SC governance and coordination mechanism	On invitation on Kerala government Coca-Cola set up the plant	Consumers: Protest against Coca-Cola plant; Kerala State government: refuse to renew Coca-Cola a license to operate; Coca-Cola case attracts international attention	Imposed to pay compensation

Potential findings and industry implication

- The resource availability assessment framework is build upon three literature domains: Natural capital theory, SC configuration theory, and Industrial ecology domain

- The resource availability assessment framework suggests that global and local resource demand in a specific location in conjunction with external environmental factors can significantly deteriorate a firm's operational environment

- As well as firm's operations can significantly affect resource availability on a specific location

- The framework seeks to deliver mechanisms to evaluate potential vulnerabilities and solutions available to firms through more proactive SC design and reconfiguration processes that account for natural resources, based primarily on network and resource attribute