Overview: This project was designed for an 8-week summer internship program, but can be adopted and adapted for a variety of research or teaching contexts. This guide will take you through the steps involved in conducting a value chain analysis of a nanomaterial or nano-enabled product. First, we present this overview of the research framework and an introduction to value chains concepts. Next is a detailed, step-by-step plan for conducting your value chain analysis. An example analysis with nanosilver is available in a separate document as part of the Template package. And visit the links provided below for examples of ways to represent a value chain graphically.

The big picture of the project is as follows:

- First you will identify who and what:
  o What are the activities, products, and markets in the nanomaterial value chain?
  o Who are the firms and countries engaging in these activities for each stage of the product life cycle?
  o Create a value chain diagram to graphically show the who and what

- Next you will investigate how and why:
  o Why are these firms and countries important?
  o How do powerful firms and institutions (or lack thereof) influence the location and success of products and markets throughout the innovation to commercialization life cycle of specific nanomaterials or products?

- You may also have an associated research question that can be addressed through your value chain analysis. Some examples of research areas include:
  o **Historical Perspective**: Did the nanomaterial or final product exist before? How is the nanomaterial enabling new products or existing current products? Can you conduct comparative analyses with other technologies?
  o **Research and Development or Innovation**: Where is innovation coming from - corporations, universities, community colleges, research centers, start-ups? What are the barriers to innovation along the value chain?
  o **Intellectual Property**: IP issues, scope, sources and number of patents
  o **Public Perception/Consumers**: Investigate consumer issues, environmental health and safety issues at different points in the value chain.

- As you complete the project, keep in mind that the information you collect can be used to develop the content for a website/webpage similar to the layout of **NC in the Global Economy**.
PART I: Introduction to Concepts Related to Value Chains

1. **A Value Chain as an Organizational Structure**
   - **Structure: What is a value chain?** A value chain is a structure that can be used to categorize and organize factors related to industrial organization: the activities, places and firms involved in making a product or service. A value chain includes the full range of activities that firms and workers do to bring a product or service from its conception to its end use and beyond. This includes the activities related to producing & transporting the product (supply chain), as well as other value-adding activities such as research, design, marketing, and support services. The activities that comprise a value chain can be contained within a single firm or divided among different firms. Value chain activities can be contained within a single geographical location or spread over wider areas. The value chain concept encompasses all stages in the innovation→commercialization process.
     - **Full Range of value-adding activities/business functions includes:** R&D, Design, Production, Logistics, Marketing, & Services
     - **The supply chain/product life cycle stages includes:** inputs, components, final products, distribution/sales, disposal/recycling

2. **Research Approach: What is a value chain approach?** A value chain approach uses the value chain concept as the organizational structure to carry out a research process. A value chain approach includes:
   - **Mapping** the internal and external linkages and geography of the chain (input-output and geography) and
   - **Identifying** dynamic variables, including governance, inter-firm relationships, upgrading, and institutions, which affect the outcomes and structural changes of the chain over time.

   a. **Mapping: What is value chain mapping?** Value chain mapping provides a comprehensive view of the geography and activities of stakeholders involved from taking a good or service from raw material to production, and then to the consumer. Value chain mapping includes activities internal (firms) and external (business and sector-specific environment) to the chain, and is represented in graphical form. Below is a general nanotechnology value chain graphic as an example.
b. **Analysis: What is value chain analysis?** Value chain analysis seeks to determine the role that various factors play in influencing the location, development and competitiveness of a product or service.
   - **Value Chain Structure:** Who performs the value-adding activities? Where do these activities take place?
   - **Value Chain Dynamics:** Which activities, organizations, and firms hold the most power in the chain? Why are they located in a certain location?

- **Benefits:** The value chain approach provides a distinction among macro, meso, and micro units of analysis used to analyze the global economy and a way to see how each factor influences the others.
  - On the macro level, it seeks to understand the roles and impacts of international institutions, organizations and standards on how and where new and existing products and technologies are developed and located;
  - On the meso level, it seeks to understand the types and impacts of inter-firm relationships and national institutions (i.e. industrial policy) on economic development and a product’s innovation to commercialization lifecycle;
  - On the micro level, it seeks to understand how individual firms and the attributes of a particular product create opportunities or risks to the development of the industry, technology, or the development of such within a particular geographic location.

The GVC research framework is divided into four building blocks that can be used to describe the structure, dynamics, and the relationships among stakeholders in global value chains. These four building blocks can be translated into steps used to carry out a value chain research approach & analysis.

- **Building Blocks 1 & 2: Value Chain Mapping**: Determine what exists and where it is located (economic organization): includes a process and methods to be used to identify and map the structural elements of the value chain, including potential qualitative and quantitative secondary & primary data sources.
  1) **Input-output**: who are the stakeholders (public and private) that currently or have the potential to develop or commercialize nano-scale materials, products and technologies? Steps and topics include:
     - Determine ways and resources to classify and collect information on products, markets, and firms
     - Conduct secondary and primary research on firms
  2) **Geography**: where do each of the links and functions in the value chain take place around the world?
     - Determine resources and methods that can be used to compare where firms, products, and markets are located (similar to above on an international level)
     - Determine a nation’s footprint in the nanotechnology value chain

- **Building Blocks 3 & 4: Analysis of value chain dynamics**: Determine how and why the current economic organization exists and how it might evolve in future by analyzing inter-firm relationships and institutions. At this point, actions and activities such as nanotechnology regulation, or offshoring of production to low-wage countries, can be compared to the value chain over time to investigate the impact of these societal factors on the technology.
  3) **Governance & Inter-firm linkages**: who are the most powerful, innovative firms in the value chain? What relationships exist among stakeholders in the chain? How do firms shape value chain structure?
     - Determine how and if relationships differ by product, market, and/or geography
     - Identify important product and firm attributes and impacts on economic development and product commercialization.
     - Identify obstacles to inter-firm linkages
     - Identify quantitative data points to measure innovation and power: may include patent, publication, funding or market data analysis
  4) **Institutions & Industrial Policy**: what are the roles and impacts of political and social; local, national and international institutions and stakeholders?
     - Compare industrial policy and its effectiveness across key countries focusing on nanotechnology: How did this develop historically & how is it playing out currently in terms of market- vs. state-driven
     - Identify the impact of the media and public and risk perception on acceptance
     - Identify environmental, health, and human safety risks and regulations (or lack-thereof)
Websites with more information on value chains and the value chain approach to research:

- Global Value Chains Initiative & Papers
- Handbook for Value Chain Research
- International Labor Organization (ILO) Value Chain Approach Guide
- USAID Value Chain Briefing Papers & Wiki
- USAID Value Chain Approach
- VCA for Policymakers & Practitioners
- WORKS project
- World Bank Value Chain Approach

Broader implications: enhance the value chain approach with your results

Due to the broadness, complexity, and general confusion surrounding nanotechnology-related topics, developing a comprehensive research approach and effective ways to present your results are just as important as your results. As part of the project, you may want to do the following:

- **Keep track of your resources to add to the Value Chain Approach steps:** A value chain approach for nanotechnology research topics currently exists in very limited form – you are breaking new ground! The following steps are only a basic outline. Since very few value chain analyses of nano-related topics have been conducted, keeping track of your work is very important for future projects. Further development of the process will enhance future projects and fulfill the need for the market interested in understanding and evaluating topics related to nanotechnology ranging from potential environmental, health, and risk impacts to understanding the innovation to commercialization lifecycle.

- **Think about how you can effectively present and communicate your research to others. This may include:**
  - Visuals & visual analytic applications that present your data in a holistic, yet systematic and simple way (a picture is worth a thousand words): 
  - **Visual representation of the supply chain (static or dynamic):** Examples of dynamic value chain visuals include the value chains on the NC in the Global Economy website. The value chains can also be used as an organizational structure to organize, store, and categorize information (e.g., NC Textile Connect and SC Textile Connect).
  - **Website:** As you collect data, think about formatting it so it can be used to create a website similar to NC in the Global Economy.
  - **Geospatial mapping:** programs such as Google Earth, Google Maps, GIS, can be used to show spatial maps of patent data, publication data, or firms. Examples:
    - **NC in the Global Economy:** Google Earth & Google Maps of Population of Firms (bottom of page)
    - **NC in the Global Economy:** Google Earth & Google Maps of Leading/Largest Firms (bottom of page)
  - **Geospatial mapping to track a product or process life cycle:** Two applications that do this are Patagonia's Footprint Chronicles (examples of global value chains/networks) and Cotton of the Carolina's: Dirt to Shirt (examples of local value chains/production networks). In each of these, companies throughout the supply chain are mapped with emphasis on environmental implications at each stage.
PART II: Nanotechnology Value Chain Research Approach:
Steps & Resources

This section of the guide walks you step-by-step through researching a complete value chain for a specific nanomaterial or nano product. There are a lot of details, so stay organized! You can use the Word document “TravelingTech_Steps_Outline.doc” as a digital worksheet to help you, which contains the headings from this part of the guide so that you can fill in the information as you go. Also, note that some of the resources listed here (full references are at the end of this document) may not be available to you. Check with your mentor and your library if you have questions about access. As a final note, the amount of detail you go into for different parts of the value chain is up to you. If you have limited time and resources, you may want to choose one area of the value chain to focus on. If you are part of a team, each member of the team can choose an area to investigate.

Things to identify before you begin: (if you are working in a team, all members should identify these in order to have a common knowledge base).

- **Keywords and spellings for your product & industry:**
  - *These can be used as search terms*
  - *Examples of nanotechnology keywords: nanotechnology, nanoparticle, nano-structure, etc.*

- **Determine the frame of reference for your project (more than one may apply). Is your project to map…**
  - … the impact of a broad concept (nanotechnology, biotechnology, information technology, sustainability) on a tangible supply chain?
  - … a specific tangible product in which a supply chain and production process can be determined (e.g. apparel, car, cell phone)?
  - … an improvement to an existing product or potential applications for a completely new product?
  - … possible supply chains included in a specific end market or distribution channel?
  - … the stakeholders that create and benefit from an intangible service (e.g. information providers, logistics firms, tourism operators)?
  - … the impact or interactions of an enabling or supporting technology or tool?

- **Understand the parts of the value chain model and how the supply chain and end markets fit in:**
  - Understand the five parts of the supply chain and determine the part you are beginning from: (1) inputs/raw materials; (2) components, (3) final products, (4) distribution & sales channels, and (5) markets.
  - Understand and determine end market channels of final products: consumer/retail or public-use channels: industrial, institutional (contract, government, hospitality, medical, etc.).
  - Understand the types of distribution channels used to sell/purchase products throughout the supply chain: (1) direct sales, (2) agents, (3) distributors, (4) jobbers, (5) other (names may differ for similar functions among industries).
• Understand the phases in the innovation to commercialization process and determine where your products fit in (Lux, 2004):
  1) Phase I: Lab
  2) Phase II: Selective Products
  3) Phase III: Mass-scale Production
  4) Phase IV: Commonplace Use
  5) For tangible products, do the input nanomaterials also exist in bulk-form (top-down) or is the nanomaterial actually created on the nano-scale (bottom-up)?

• Identify products, firms, and industry statistics (market size, funding, patents, publications, etc.) in industry classification systems
  o To identify U.S. firms and products:
    ▪ NAICS: North American Industrial Classification System
    ▪ SIC: Standard Industrial Classification System: predates NAICS, but still used
  o To identify products and countries in international trade:
    ▪ Standard International Trade Classification (SITC): UN COMTRADE is the main resource using this system
    ▪ Harmonized System (HS): global, six-digit product classification system
    ▪ U.S. Harmonized Tariff System (HTS): administered by the U.S. International Trade Commission (USITC) for U.S. imports. A similar system called Schedule B codes are based on the HTS codes, and administered by the U.S. Census Bureau to measure U.S. exports.
    ▪ Trade Stats Express and USITC Dataweb: U.S. trade data resources
  o To identify patents and firms with patents:
    ▪ International Patent Classification (IPC) System: version 2009.01
      ▪ Sections: B: Performing operations; transporting
      ▪ Subsections: Micro-structural technology; nano-technology
      ▪ Classes: B82: Nano-technology
      ▪ Subclasses: B82B: Nano-structures; manufacture or treatment thereof
      ▪ Group: B82B 1/00: Nano-structures
      ▪ Group: B82B 3/00: Manufacture or treatment of nano-structures
    ▪ U.S. Patent Classification (USPTO): Class 977: Nanotechnology (est. in 2004)
    ▪ Chinese State Intellectual Property Office (SIPO)
    ▪ European Patent Office Class (EPO): Class Y01N: Nanotechnology
      ▪ ‘Y’: General Tagging of New Technological Developments; ‘01’: Broad Technical Fields Identified by Dimensional Aspects; ‘N’: Nanotechnology
      ▪ Y01N2: Nanobiotechnology
      ▪ Y01N4: Nanotechnology for information processing, storage or transmission
      ▪ Y01N6: Nanotechnology for materials or surface science
      ▪ Y01N8: Nanotechnology for interacting, sensing or actuating
      ▪ Y01N10: Nanooptics
      ▪ Y01N12: Nanomagnetics

1 Subclass does not cover chemical or biological structures provided for elsewhere (e.g. in classes C08 or C12).
Value Chain Mapping Steps

STEP 1: Read industry overviews, surveys and market reports. Identify the following for your nanomaterial:

- Keywords: keep an ongoing list of keywords for your industry/products. These can be used as search terms.
- Definition
- Purpose
- History
- Properties
- Synthesis (production techniques to manufacture)
- Key Applications
- Drivers of Innovation
- Momentum for Commercialization
- Challenges

Nanotechnology-Specific Resources to use:

- Lux Sizing the Nanotechnology Value Chain (2004)
- Plunkett Industry Overview & Glossary of Nanotechnology Terms
- CRCnetBASE: NANOnetBASE (Available at UCSB and Duke libraries)
- CRS Nanotechnology Policy Primer (2009)

Industry and Market Research Databases:

  - Semiconductors (33329a)
  - Plastics & Rubber Machinery (33322)
  - Electronic & Computer Repair Services (81121)
  - Scientific Research & Development (54171)
  - Paint Manufacturing (32551)
  - Pharmaceutical & Medicine Mfg (32541)
  - Battery Mfg (33591)
- Industry and Market Reports that do not have nanotechnology-specific reports as of May 2008: Standard & Poor Industry Surveys: Datamonitor and Euromonitor.

STEP 2: Identify Supporting Environment and Institutions

Who else is involved in or has interest in your nanomaterial? Think about who these stakeholders are, and where they are located. You may identify several for your material from the list below.

Key Groups of Stakeholders and Activities

- Research
- Finance and Funding
- Risk and Safety
• Intellectual Property  
• Standards and Testing  
• Training and Education  
• Economic Development

Categories of Stakeholders:  
• Government  
• Industry Associations  
• Universities, Community Colleges, K-12  
• NGOs  
• Business, Technology, and Service Providers

Geographic Levels of Scope:  
• International, Regional, National, and Local

Resources:  
• Plunkett’s Organizations and Associations Database (2008 & 2010)  
• NSTC-NSET NNI Workshop Results: Regional, State, and Local Nanotechnology Initiatives (2003) & (2009)

STEP 3: Identify firm participants  
Which companies are involved with your nanomaterial? To keep yourself organized, you may want to make a spreadsheet like this one to fill in key information for each firm.

Databases of Nanotechnology-Related Firms:  
• Lux Nano Reports, 4th & 5th Editions, vol. II: Company Profiles  
• Plunkett's Nanotechnology Company Listings: 2008 and 2010  
• Plunkett Associations & Organizations Listings: 2008 and 2010  
• Woodrow Wilson Center Consumer Product Inventory

Once you identify the names of products or firms, you can access these databases via the library website or in hard copy at the library for company/product data. If NAICS codes can be determined, you can identify the population of firms with D&B or ReferenceUSA. If NAICS cannot be determined, individual firms can also be searched in these databases.

• Dun & Bradstreet/Hoovers  
• Reference USA  
• Euromonitor  
• Mergent Industry review  
• Lexis Nexis Academic: includes access to the following resources: Hoovers, Standard and Poor's, Value Line Investment Survey, Thomas, and Directory of Corporate Affiliations

STEP 4: Create the supply chain (see nanotechnology value chain image)

Stage 1: Identify nanomaterial classification from the following list:  
Nanoporous materials (zeolites); or
Nanoparticles: all classifications below can be referred to as forms of nanoparticles. The nanoparticle classification can be further classified into (Lux):
  o Nanoscale in one dimension: flat nanoparticles (i.e. nanoclays)
  o Nanoscale in two dimensions: nanotubes, nanowires, etc.
  o Nanoscale in three dimensions: spherical nanoparticles
1) Nanostructured Metals: usually refers to upgrading existing alloys: lead (steel) or cobalt. Can also be a nano-structured version of bulk metal: copper, zinc, titanium
2) Metal Nanoparticles: silver, gold, aluminum, nickel
3) Ceramic Nanoparticles: includes metal oxides: Titanium dioxide (TiO₂), Cerium oxide (CeO₂), Zinc oxide (ZnO₂), Iron oxide (FeO₂), Silicon dioxide (SiO₂), Aluminum oxide (AlO) and hydroxide (AlOH) and nano clay.
4) Dendrimers
5) Nanowires: wires with diameters less than 100 nm; nano in two dimensions
6) Carbon Nanotubes (CNT): SWNT or MWNT
7) Quantum Dots: nano-sized crystals of semiconductor or metal materials
8) Fullerenes: C60, bucky balls, or buckminster fullerenes

Nanomaterial Resources
  o Lux Nanotech Report, 4th & 5th editions, vol. I
  o Freedonia Focus on Nanomaterials: 2007, 2009, and 2010

Stage 2: Identify nanointermediate classification from the following list (Lux 4th ed.): Nanointermediates can be classified as (1) intermediates with nanostructured features or (2) intermediates containing nanoparticles:
  o Nanocoatings
  o Nanosensors
  o Nanotherapeutics
  o Nanocomposite materials
  o Nano-enabled diagnostics
  o Nano-enabled displays
  o Nano-enabled drug delivery systems
  o Nano-enabled memory
  o Nano-enabled solar cells
  o Nanointermediates

Resources
  o Freedonia Focus: Nanocomposites: 2008

Stage 3: Identify nano-enabled (final) products and markets
Note: Lux classifies nano-enabled final products as either (1) final products with nanostructured features or (2) final products containing nanoparticles. Nanomaterials, intermediates, final products, or tools can be associated with end-use markets.
End-Use Markets with Product and Firm Examples:
- **Electronics & IT** (Lux and Freedonia): Examples: cell phone, computer
- **Manufacturing & Materials** (Lux): Examples: construction, consumer vehicles, plastic reinforcements (composites)
- **Healthcare & Life Sciences** (Lux and Freedonia): Examples: sunscreen, pharmaceuticals
- **Energy** (Freedonia): Examples: batteries, fuel cells, solar cells

Nano-Enabled Final Product Resources
- Woodrow Wilson Center (PEN): Inventory of consumer products includes: 806 products, 484 companies, and 24 countries.

**Stage 4: Identify the types of tools needed in the following nano tool classifications** (Lux, 4th & 5th ed.)
- **Fabrication tools:** includes: nanodevices
- **Modeling tools**
- **Inspection tools:** or instrumentation: includes: atomic force microscopy (AFM), scanning electron microscopy (SEM), transmission electron microscopy (TEM), differential scanning calorimetry, x-ray photoelectron spectroscopy, fourier transform infrared spectroscopy, magnetic resonance imaging, confocal laser scanning, laser scanning microscopy, x-ray diffraction, and mass spectrometry.

Optional Step 5
1) To go beyond considering just a nanomaterial, repeat steps 1-4 (specifically Step 4) for a final product from one of the four final product markets or a location.

**Example value chain for nanosilver**
We have created a value chain for nanosilver as an example, in a separate document. Compare the example to these steps to help you understand what your value chain research data may look like.

**Using the nanotechnology value chain**
Now that you have constructed the value chain for a specific nanomaterial, technology or product, you can use it as a tool for investigating research questions. Below are examples of social science research areas and how you can approach them using a value chain framework.

**Example research area: Risk, Regulation, & Public Perception**
**Identify supporting environment, institutional actors, risks, & policies**
- **Key groupings of institutional actors:** corporations, start-ups, NGOs, Regulatory Agencies, Insurers, Toxicology researchers, journalists, and consumers
- Plunkett’s Nanotechnology List: Associations/Organizations (Plunkett, 2008)
- CRS Nanotechnology: Policy Primer (Sargent, 2009)
- CRS National Nanotechnology Initiative (Sargent, 2008c)
- CRS Federal Support for Nanotechnology Research 2007
- CRS Nanotechnology & Environment, Health, Safety (Sargent, 2008a)
- CRS Engineered Nanoscale Material/Regulatory Challenges (Schierow, 2008)
- Lux Nanotech Report Nanotech Environmental, Health & Safety Risk (Lux 2006; 2007)
- Project on Emerging Technologies: Environment, Health & Safety Research

- **Investigate the three types of risk:**
  1. **Regulation**
     - Voluntary reporting
     - Codes of conduct
     - Standards: national and international initiatives
  2. **Exposure risk:** exposure and hazard; affects humans and the environment
  3. **Risk perception:** public perception: no formula exists: media exposure

**Example research area: Innovation & Communication: Inter-Firm Linkages**
Identify linkages in the value chain by analyzing statistics on funding sources, patents, publications, & firms. Identify barriers and missing, and needed linkages

**General Resources:**
- Barriers to the Diffusion of Nanotechnology (2008)
- Nanopatenting Patterns in Relation to Product Life Cycle: (Alencar 2007)
- USDOC: Report on the Barriers to Nanotechnology Commercialization (2007)

**Related to Firms and/or Geographic Clusters:**
- Project on Emerging Nanotechnologies: ([US NanoMetro Map](#))
- Emergence of Nanodistricts in the United States: (Shapira & Youtie 2008)

**Related to Nano Funding:**
- Plunkett: Industry Statistics 2008 and 2010

**Related to Patents & IP:**
- Lux Report, 5th ed., vol I, Chapter 3: Technology Profiles (profiles have a section on IP outlook & patent statistics) pg. 54-200
- Lux Report, 4th ed., vol. I: Key Patents: each category has a section on key patents

**Related to Publications:**
- Nanotechnology publications & citations by leading countries & blocs (Youtie 2008)

**Research area: Globalization & Governance**
**Identify Leading Firms (& common strategies) and Countries (or states)**
Helpful Resources to Identify:

- **Company Profiles and Corporate Structure:**
  - Lexis Nexis Academic: Corporate Affiliations
  - Edgar 10K Filings
- **Product Leaders:**
  - OneSource, Hoovers, Plunkett's, Mergent Online, Standard & Poor's, & Datamonitor

- **Market Leaders:**
  - Mintel Reports, Hoovers, Euromonitor, OneSource, & Plunkett's

- **Global Leadership:**
  - Lux Nanotech Report, 4th and 5th ed., vol. I: section on key companies for each classification
  - OneSource, Plunkett's, Euromonitor, & Mergent Online

- **Leading Countries or States:**
  - Historic country leaders: Investext
  - Present: OneSource, Datamonitor, Plunkett's, US Commercial Service Reports, Trade Data (Trade Stats Express, USITC, SITC, UN Comtrade)
  - U.S. States: if NAICS can be identified, use the 2002 or 2007 Census
  - Project on Emerging Nanotechnologies ([U.S. NanoMetro Map](#))

**Research Objectives:** in-depth analysis of leading firms and product attributes to identify sources of firm power and upgrading strategies in the value chain:
- **Capabilities:** identify the population of firms and how capabilities changed over time
- **Complexity:** does adding nano features to a product or process make the process more difficult? How does this vary by product and technology?
- **Codifiability:** how have advancements in technology and processing affected supply chain logistics?
Resources


