Advanced Analytics in Action: a manufacturing plant cost index for strategic network design

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Abstract

The purpose of the paper is to present how Syngenta, a leading global company in crop protection and seeds responds to the challenges of network design using advanced analytics tools. It contributes to the topic of supply chain transformation enabled by digital technologies, addressed in the Cambridge International Manufacturing Symposium by presenting a manufacturing plan cost index for strategic network design. It further aims to make a connection between published frameworks (Institute for Manufacturing) and their applicability to a corporate environment and also address capabilities of advanced analytics and modelling technologies.

Keywords: plant; costing index; network design; advanced analytics

1. Introduction

The recent anti-globalization rhetoric and protectionist policies have made the task of developing global supply chain network design more difficult. In times of increasingly uncertain, volatile markets and industry consolidation, business analytics and organizational expertise are becoming a relevant contributor to the long-term strategy of multinational companies by informing and influencing decisions in an educated way. A variety of business analytics tools and capabilities are in place to support top management's strategic decision-making.

Syngenta is a global manufacturer that serves the market of fungicides, herbicides, insecticides and seeds around the world. Its global supply chains are multistage networks with many possible paths from the source of active ingredient (AI) to the destination country of final products. Its manufacturing processes are divergent. This means that there are hundreds of different final products are made from one active ingredient. At each intermediate stage in the supply chain, the number of products or intermediate products increases and the number of possible facilities for manufacture and distribution also increases. In the highly regulated business environment of agricultural chemicals, the country of origin of an active ingredient can determine where the final product can be marketed and the amount of taxes and duties applied to the product. Taxes, duties, and tariffs can consume up to 40% of the revenue brought in by a product and the route that a batch of product takes through the supply chain network can greatly impact how the batch is taxed.

The aim of this paper is to further contribute to the topic of supply chain network design by showing how the company responds to strategic issues in supply chain network design using advanced analytics tools. In particular, it addresses the following research questions:

1. How Syngenta deploys supply chain network design assessments?
2. What is a typical plant costing approach used in formulation technology clusters assessments?

2. Strategic network design in Syngenta

Syngenta is a global leading agribusiness providing solutions in crop protection products and seeds. The company occupies the number 1 position in terms of global market share for crop protection products, and is third in the seeds market (Reuters, 2017). The company has recently been acquired by ChemChina in a $43bn deal as part of a trend which has seen considerable consolidation within the industry. As part of the sale terms Syngenta have been forced to sell some products to other firms in order to comply with anti-trust remedies (Syngenta, 2017).

The company is proud of its strong R&D productivity and in 2015 boasted the highest Sales Income to R&D ratio within the industry (Syngenta, 2015). The company has a strong product pipeline with 7 new lead crop protection products expected to be introduced around 2022. This poses opportunities and challenges with supply chain development for new products whilst Syngenta rationalizes its existing portfolio to comply with remedies, and also seeks to take advantage of remedies for other mergers within the industry (Bloomberg, 2017) whilst rival firms are also following the current trend for active manufacture involves multi-stage chemistry with several chemical reactions. The overall end to end supply chain for a typical active ingredient is mapped out below in Figure 1.

Customers located across the world have differing requirements ranging from packaging size, mixture products i.e. formulated with other active ingredients to target different pests, and different spraying seasons this is despite the active ingredient being identical. Therefore typically the supply chain is decoupled after active ingredient manufacture, i.e. before formulating the product. This is dependent on the individual active ingredient, and in some cases there is a standard premix solution which can be formulated and stored allowing later customisation. There is also the possibility to decouple after fill and pack, however when developing a supply chain for a new active ingredient with relatively uncertain forecasting this would seem to be unwise as individual products/SKU's may have higher or lower demands than expected and regional demand may vary significantly.

For Supply Chain Network Design, an important tool is the usage of analytics technologies considering data collection and reporting, network modelling and simulation as well as analytics for visualization and communication. Table 1 shows the deployment of various analytics tools, as part of standard supply chain network design procedure.

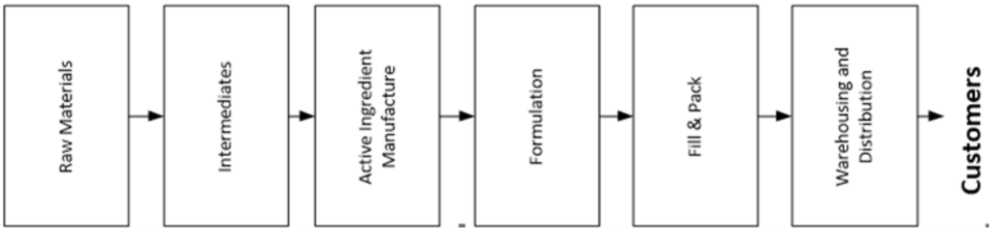

Figure 1 End to End Supply Chain for active ingredient

3. Literature review

3.1. Strategic issues in supply chain network design: a review of latest insights

In the last 30 years, as companies have extended their global reach to access new markets and resources, the academic study of global production networks has accelerated in parallel. Arguably, the earliest work in the area goes back to the 1960s, and by the 1980s and 90s researchers were starting to identify the importance of considering the production network as a whole rather than focusing on factories in isolation.

Global supply chain strategy and network design can be developed using different approaches and enablers. Examples in literature include product based strategies (Fischer, 1997), designed vs implemented strategies (Withington, 1996), blue ocean strategies (Chan Kim, 2015), Conceptual System Assessment and Reformulation (CSAR) (Perez- Franco, et al., 2016), foresight based strategies (Darkow, 2014) and data driven strategies (IfM, 2017). Considering the topic of strategic network design, there is a plenty of recent scientific research. The main focus can be categorized in the three big categories:

- *Supply chain strategy and global supply chain network design perspectives:* (HBR, 2005) ; (Vereecke et al., 2008) ; (Melo et al., 2009) ; (Ferdows et al., 2016); (Pibernik, 2017) ; (IfM, 2017) ; (Desmet, 2018) ; (Blokdyk, 2018).

- *Operations research models and network optimization focus:* (Boonmee et al., 2017) ; (de Keizer et al., 2017) ; (Farahani et al., 2010) ; (Melo et al., 2010) ; (Martel & Klibi, 2016) ; (Bassett & Gardner, 2013) ; (Catt, 2007) ; (de Kok & Graves, 2003).

- *Strategy development or strategy as practice focus*: (Fischer, 1997) ; (Darkow, 2014) ; (Chan Kim, 2015) ; (IfM, 2017).

According to Perez- Franco et al. (2016) supply chain strategy of a business unit (BU) is the collection of general and specific objectives set for the supply chain of the BU, the decisions and policies to support them, with the purpose that supply chain strategy supports the overall business strategy, given the BUs characteristics and specifics. Past consolidated research (Hofmann, 2010; Kahn, 2007) clearly indicated that strong are the links between business unit strategies with supply chain strategies and capabilities, especially on the global network design level which can be used as a lever for corporate strategy. Same research concludes that an alignment between corporate strategy and supply chain strategy impacts the performance of the corporation. However, it's not only performance affected; there is a whole set of factors that drive optimization, and, depending on the political and economic context, they tend to have different weighted factors. Meixell (2005) differentiated between "on-going" strategic factors and "emerging" factors of consideration with regards to globalization. A recent study by SCM (2018) makes similar classification and addresses that apart from cost which remains paramount factor, "emerging" strategic factors could be considered the following:

-*Increasing cost of long distance supply chains and long lead times:* One reason for this phenomenon is consolidation in the international logistics industry. The bankruptcy of shipping companies such as Hanjin Shipping Company last year reduced capacity, increased congestion and pushed up ocean and air freight prices. In Syngenta, a recent assessment on AME networks showed that direct sales to AME in case of AI production outside EAME reason could last up 12 weeks only from logistics perspective.

-*Flexibility and agility have become critical network features:* Unexpected closure of suppliers especially in Asia due to bankruptcy or due to changes in regulation lead to capacity problem. Thus supply networks are less flexible, more costly but also extend what may already be long lead times even further (SCM World, 2018).

-*National regulations are tending to be in favor of localization:* Local content, manufacturing and packaging rules, import regulations, and differing safety/quality standards are among the laws that are forcing many Western companies away from global operations and towards building up local supply bases to support them (eg. USA, AME, India, Russia, Brazil, China etc.):

- China: government policy actively favors local firms and is making it harder for outsiders to operate extended supply chains in sectors such as high-tech equipment and pharmaceuticals (SCM World, 2018).
- Russia: government introduced +20% duty barriers for agrochemical products.
- North America and EU cancelled development of transpacific agreement.

-*Global trade factors are more significant than in the past*: Tariffs have for sure moved up the agenda during the past decade. The cost equation is fulfilled with duties, tax rates, currency exchange movements, international sanctions (Qatar being a recent casualty) and government incentives to set up local manufacturing operations. In the this environment, monitoring negotiations around free-trade agreements such as NAFTA, ASEAN, Mercosur, EU, EEU as well identifying countries with a wide network of 1-1 free trade agreements such as Singapore is a must, since the imposition of both tariffs and non-tariff barriers can have a huge impact on network dynamics.

3.2. Strategic network design foundation: scientific frameworks for reference

Considering those strategic issues, it seems that the equation of network design assessment is a complex one and needs a structured framework to approach it. In past lots of approaches have been developed with regards to how to approach those problems. For the purposes of this study, the authors consider the model delayering the global production network into congruent subnetworks and considering plant typology developed by Ferdows, Vereecke and De Meyer at 2016 and the practical approach of IfM and Cambridge University for designing global networks for competitive advantage (2007) (Figures 2 and 3).

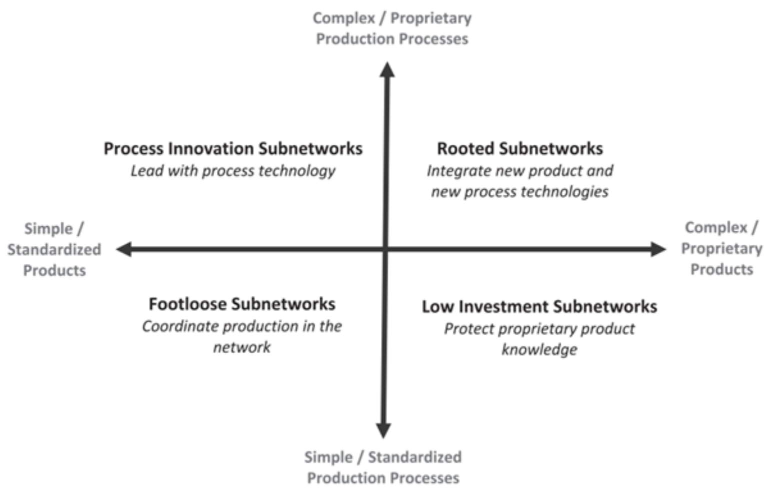

Figure 2 Framework for gauging plant subnetworks

Ferdows, Vereecke and De Meyer (2016) stated that each subnetwork can fall in one of the four quadrants based on the complexity and proprietary knowledge embedded in their products and production processes: the rooted subnetworks, the footloose subnetworks, the process innovation networks, and the low investment subnetworks.

The Process Innovation Subnetworks (top-left quadrant) use sophisticated and proprietary production processes to produce rather simple and commodity type products. The purpose of them is process innovation, which can be easier if some of the plants in these subnetworks are in environments with advanced sophistication usually found in industrialized countries. Due to leakage of best practices along the time, a proprietary process is not likely to remain proprietary after a few years, and if these subnetworks do not keep up with process innovation, they are likely to slip to the bottom-left quadrant (Ferdows et al., 2016). This category is relevant for the agrochemicals. For example, Syngenta water granular product groups belong in this category.

Low Investment Subnetworks (bottom-right quadrant) make mostly proprietary products using production processes that are standard in the industry. Plants in these category are not a source of competitive advantage for the company. Many subnetworks in the chemical industry are in this quadrant. The usual mission for these subnetworks is to supply reliable quality and quantity of products at the right time and place and to minimize the danger of leakage of the proprietary product knowledge (Ferdows et al., 2016). For example, Syngenta seed care product groups belong in this category.

Rooted Subnetworks (top-right quadrant) produce products with unique and often advanced designs (e.g. electronics). The products of these networks usually need to be supported by continuous research and their advanced and rather sophisticated process technologies must also be frequently upgraded. They usually have "centres of excellence" as they are continuously developing supply and production capabilities (Ferdows et al., 2016). In Agrochemical industry and in Syngenta in particular, this category is not really applicable.

Footloose Subnetworks (bottom-left quadrant) produce commodity-type products using production processes that are standard in the industry. The purpose of these plants is usually minimizing production costs while meeting required quality and delivery specifications; hence, being located in low-cost environments would generally be advantageous for the plants in these subnetworks (Ferdows et al., 2016). This category is relevant for chemical industry with growing % of market share covered by generic companies mid-tiers, mature products etc.

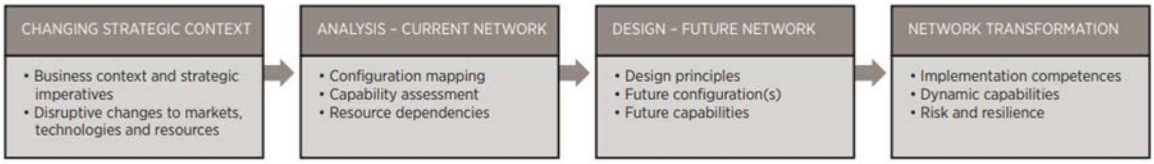

Figure 3 A practical approach for strategic network design developed by Cambridge Institute for Manufacturing

Figure 3 shows the practical approach developed by IfM for network design assessments. The first step is to understand the framework for analysis, and to tailor it to the needs of the particular organisation. This involves laying out the master process itself, creating basic definitions and defining simplifying assumptions (IfM, 2007). This phase includes an analysis of the change of strategic context. This typically covers the business and technology drivers relating to the scope of the challenge – and resulting in clear articulation of the strategic imperatives. The question what is the purpose of the new network is a basic outcome of this phase (Singh Srai & Christodoulou, 2014).

In the light of the application of this approach in large organisations is to split the problem into manageable pieces, and this normally involves separate analysis by global product group. This is because families of products tend to have similarities in terms of production characteristics and market requirements. When the approach is clear, the basic structure of the network needs to be defined in terms of plant purpose and the principles for coordinating them.

Once this is established then footprint options are then assessed using a balanced set of strategic performance criteria. The process of optimising across product groups, here termed 'aggregation', is a crucial step because significant synergies can be generated through shared assets and overheads. The enterprise solution is then tested against different views of the future and key risks. This is essentially a highly iterative process, with two key feedback loops; refinement of product group footprints based on assessed performance and refinement of enterprise solutions to make them more robust to possible risks and changes in world conditions.

Table 1 Analytics tools deployed for network design assessments

Tool	Realization
SAP Reporting tools	Demand & Sales, shipped quantities to customers, quantities of product transported between facilities (nodes) over applicable shipping route warehouse operation prices, transportation prices, warehouse costs, transportation costs, average monthly inventory, capacities, transportation routes.
Excel templates for data collection	Standardization of data collection for future network changes and data & information communication to stakeholders.
GT Nexus (Infor)	End-to-End logistics visibility including cost, performance.
Supply Chain Guru (Llamasoft)	Network Modelling and scenario realization.
Tableau	Segmentation and cohort analysis → Calculated Fields, Clustering, Sets, Groups Scenario and what if analysis → Parameters, Stories Sophisticated calculations → Quick Table Calculations, Statistical Functions Time-Series and Predictive Analysis

4. A development of cost benchmark index for manufacturing plants in Syngenta using the concept of morphological analysis

Formulation technology clusters is high in the agenda of supply chain network design assessments. The main objective of those projects is

- to inform strategy decisions,

- to analyse specific formulation technology clusters,
- to inform investment or siting decisions.

Figure 4 shows a morphological analysis for classifying assets of formulation that can be used in asset management strategy and strategic network design.

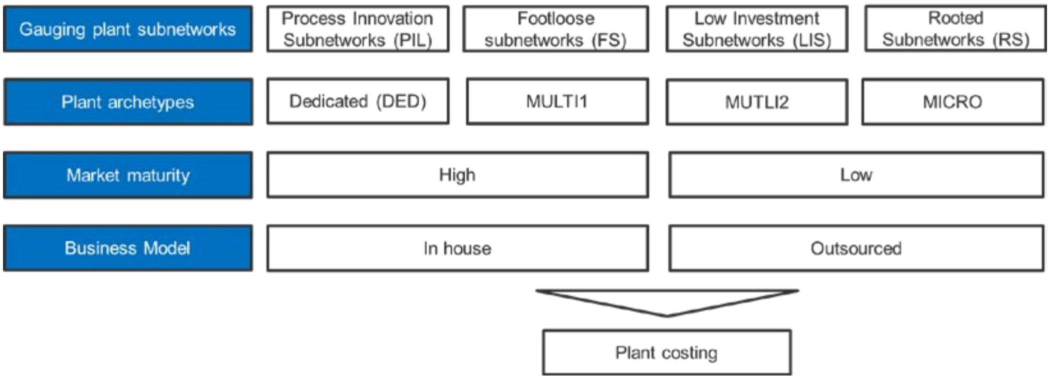

Figure 4 Formulation asset management strategy morphological analysis

The framework contains four elements: the gauging plant subnetworks, the plant archetypes, the market maturity and the classification between in house or outsourced plants. The combination of those our elements lead to a benchmark of plant costing index that can be used as input when evaluating formulation technology clusters.

The gauging of plant subnetworks is the classification of Ferdows, Vereecke and De Meyer refereed in chapter 2 of this paper. Based on what is discussed above, agrochemical industry and Syngenta in particular manly operate Process Innovation Networks (PIN), Footloose Networks (FN) and Low Investment Subnetworks (LIS). The Rooted Subnetworks products usually need to be supported by continuous research and their advanced and rather sophisticated process technologies must also be frequently upgraded. Plants in these subnetworks need stability. Building deep expertise in both product and process technologies takes time and, because the knowledge behind this expertise is usually in tacit form, much of it must be developed locally, in interaction between engineering and production (Pisano and Shih, 2012). Thus, those plants should stay in place for long periods and locations and operations is not challenged. This is not the case for agrochemicals because, as stated in the literature review, national and global regulations and global trade factors affect the fit for purpose network alongside time (Ferdows et al 2016).

The second element of the classification framework is the classification of manufacturing assets into archetypes that cover the needs of product portfolio. An assessment of the current & future Syngenta CP product portfolio shows that an “A FEW SIZES FIT MOST” philosophy sets the right balance between standardization and distinct approaches to manufacturing. Four formulation asset archetypes cover the needs of the majority of Syngenta’s product portfolio:

- DEDICATED (DED): Production lines dedicated to one product
- MULTIPRODUCT 1 (MULTI1): Production lines for few products of higher volume
- MULTIPRODUCT 2 (MULTI2): Production lines for many products of significant but lower volume
- MICROPRODUCT (MICRO): Production lines for a very large number of small volume products

Majority of existing formulation lines correspond to one of the first 3 archetypes. The current lack of assets designed to the MICROPRODUCT archetype creates significant operational complexity and thus an opportunity for the design of Syngenta's future asset network footprint. The majority of the Syngenta portfolio sits in "Multiproduct 1" and "Multiproduct 2" archetypes. As a result, production lines of these archetypes are typically required for each formulation type in all geographies. In order to keep inventory at a manageable level, production campaigns of each product are required every month or at least during peak season. Dedicated and micro-product lines typically serve multiple geographies in order to maximize economies of scale and scope respectively. The location of these lines is driven by considerations such as proximity to AI manufacture and opportunity to consolidate inventory. For instance, it makes most sense to co-locate "Microproduct" archetypes with "Multiproduct 2" production lines where there is already good access to many AIs.

The third element of the framework is the market maturity. The business portfolio split (crop protection products) currently is 20% APAC, 30% EAME, 25% LATAM and 25% US. Considering APAC and LATAM as emerging markets, the split between mature and immature markets is 45% vs 55%. The business practical elements of differentiation between mature and immature markets is the technological value (Selinger, 2012) (Figure 5) the end-to-end manufacturing costs and the economic trade landscape that overrides the geographic segmentation. As tax & duty are a far bigger driver for end-to-end costs than formulation manufacture fixed cost, "geographies" in this context are largely driven by the trade landscape (e.g. MERCOSUR, NAFTA, EU / EFTA). Often this aligns with Syngenta's "Regions" or "Territories"; however, certain important exceptions require a different approach, e.g. Pakistan, Bangladesh and India cannot be treated jointly as "South Asia". As the economic trade landscape can change over time, there is a significant benefit to building in flexibility to the network design (through source registration strategy and appropriate capacity headroom), especially for products that contribute significant profit.

The fourth element of the morphological analysis is the differentiation between an outsourced or in-house plant. In any large organization like Syngenta, there are likely to have a number of different approaches to the make-or-buy decision. The motives for using external sources is the cost reduction, the avoidance of capital expenditure, the standardization, the market access, the multiple supply and the tax incentives (eg. free-trade-areas). The framework shown in Figure 7 is an approach developed by IfM and to a certain formulated product groups is used in

Syngenta context. Outsourcing, introduces a number of risks in terms of quality, continuity of supply, loss of control and creation of new competitors, thus, cost should not be the only driving factor for such decisions.

- personality development
  - e.g. freedom of action and creativity
- societal quality
  - e.g. justice, solidarity and transparency
- prosperity
  - e.g. satisfaction of demand, competitiveness
- economy
  - e.g. profitability and efficiency
- environmental quality
  - e.g. protection of landscapes and species, use of natural resources reduction of emissions
- health
  - e.g. physical/psychological well-being, life expectancy
- functionality
  - e.g. usefulness, feasibility and effectiveness.
- safety
  - e.g. reduction of economical risk

Figure 5 Criteria for technological value according to VDI Guideline 3780 (source VDI 3780)

The final element is the price differentiation. Here a fundamental assumption is being used for this classification. Basis is considered to be the 100% and it belongs to own plants with high volume (>1 Mio Litter). Then three basic variations are created: cheaper option 25% (price 75%), more expensive option 25% (125%) and more expensive option 50% (150%). This approach allows calculation of the formulation production cost. This includes all formulation, UC (bulk chemical) variable costs and allocated fixed cost, without considering the cost of Active Ingredient and Row material. Moreover, it allows to design the basis for network design scenario calculations and introduces the element of cost efficiency. Assuming that formulation "Formulation 1" for product "Product 1" now is produced at "Plant 1" which is an owned plant and costs 1.60 USD/L, in the future, it could be produced in other plants with calculated cost as per previous adjustments

5. A cost index for manufacturing plants using a Syngenta case

It's understandable that there are a lot of possible combinations considering the framework of Figure 4. For this reason, the authors decided to use a past case to develop the cost index. For the purpose of the analysis, the practical approach developed by IfM is used. The scope includes the product group of insecticides/fungicides which have a common production technology (EC) with 30+ plants globally. It is a formulation technology cluster assessment because it targets to inform formulation strategy decisions. The volume split of products globally is as per following:

- ASIA PACIFIC: 39%
- EUROPE & AME: 31%
- LATIN AMERICA: 27%
- NORTH AMERICA: 3%

EC Technology (Emulsifiable Concentrate) is a formulation technology that contain one or more active ingredients, one or more organic solvents, one or more emulsifiers and other inert ingredients like safeners, stabilizers, adjuvants, defoamer, thickeners and dyes. From manufacturing and production requirements, this technology is easy to produce in common EC formulation plants and requires lowest raw material cost – no exotic, expensive or difficult to source ingredients.

Changing strategic context

This includes the consideration of business context and strategic imperatives as well as the disruptive changes to the market and technologies. The 5 year capacity plan assumes a lot of unutilized capacity for the years 2017-2022 (Figure 6). Moreover, there are constraints with recent launches of NPI's in EAME and LATAM.

Ins/Fung EC in (Multiple Items)

	2017	2018	2019	2020	2021
Quarter	20%	21%	21%	21%	22%
Semester	19%	20%	20%	20%	21%
Annual	18%	18%	19%	19%	20%

Figure 6 Global capacity vs demand

At the same time, the inventory picture for the group of products follows a different pattern. Driven by a combination of factors despite available capacities FPP stock coverages are growing (Table 2).

Table 2 Inventory coverage differences 2014-2016

	Coverage	
Active ingredient 1	2%	-10%
Active ingredient 2	86%	20%
Active ingredient 3	-18%	-1%

Active ingredient 4	35%	14%
Active ingredient 5	16%	3%
Total	**35%**	**8%**

Having this strategic context in mind, the following questions were considered as objectives of the network design assessment:

- *Is existing EC Formulation cluster set-up aligned with main products lifecycle stage being at maturity?*
- *How should the formulation assets network 2021+ look like?*

Analysis-Current network

As a next step, the analysis of current network needs to be performed. This step requires the deployment of advanced analytics tools including templates for data collection, Supply Chain Guru for network modelling and Tableau for visualization. In Parallel with the baseline network, one other variations have been explored: the unconstrained network. This removes all the constraints and allows the network to be designed from scratch. Figure 7 shows the depiction of the current network output by using Tableau.

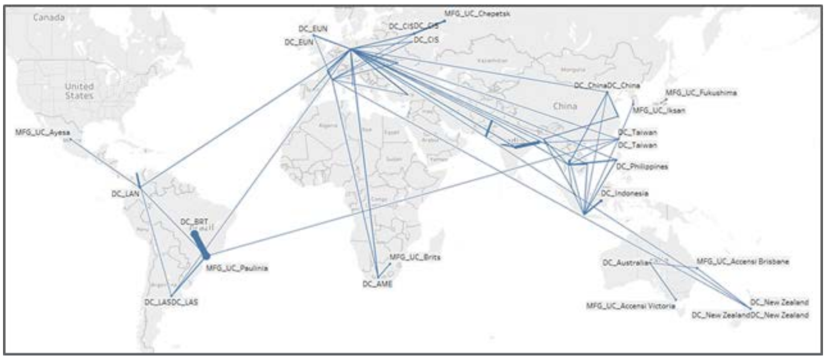

Figure 7 Analysis-Current network using Tableau

As part of the as-is analysis, an important elements is the network mapping configuration. Considering the classification of De Meyer, the as-is network is a low investment subnetwork with major focus the protection of proprietary product knowledge. In general, plants in these subnetworks are not a source of competitive advantage for a company. Another critical mission is to reduce the risk of leakage of the proprietary product knowledge. For example, even if these subnetworks include plants by subcontractors and suppliers, the company often controls or owns many of the special tools, molds, or machinery for making its products. Still, there is often a high emphasis placed on maintaining confidentiality. This may motivate the company to keep many plants in these subnetworks in countries with reliable and enforceable laws, even if they are in a high-cost environment, to mitigate the risk of losing control of its brand image and proprietary information. Mitigating this risk can be a strong motivation for reshoring the offshored plants in this quadrant (Ferdows et al., 2006). The majority of products belong to the categories MULTI1 and MULTI2, and the business model is a mix of outsourced and in-house plants.

As it was shown in Figure 6, there are currently a lot of cross-regional movements. This means that in certain locations, formulation production cost might be lower compared to others, but in the total network cost someone needs to consider the duty cost both for upstream and downstream supply chain. A closer observation lead to the conclusion that there are plants in non-FTA areas. Overall, the drivers of optimization are:

-Excessive existing capacity

-Plants in non FTA

-Plants with different cost efficiency

Analysis-Future Network

A very important observation here is the categorization of plants to different categories based on formulation production cost. A careful review of the as-is network concludes that those 30 production plants, someone could classify them in different high level categories:

i) Class A: Plants owned by Syngenta 1 Million Litter +

ii) Class B: Plants owned by Syngenta 0.3- 1 Million Litter

iii) Class C: Toller more expensive than own 1 ML + class plant

iv) Class D: Toller as costly as own class 1 ML + plants

v) Class E: Toller cheaper than own class 1 ML plants

Taking into consideration the analysis presented in Chapter 4, the authors have developed an index for manufacturing plant costing that it is shown in Table 5. Table 3 shows all potential different combinations for LIS subnetworks that EC technology operates. It mainly distinguishes between two product types following the Pareto logic: Top products and non-top products. This plant classification:

- allows calculation of the formulation production cost. This includes all formulation, UC (bulk chemical) variable costs and allocated fixed cost, without considering the cost of Active Ingredient and Row material
- allows to design the basis for scenario calculations. Assuming that formulation “Formulation 1”, product “Product 1” now is produced at “Plant 1” which is classified as class D and costs 1.60 USD/kg, in the future, it could be produced in other plants with calculated cost:

-Class A: 1.61

-Class B: 2.01

-Class C: 2.41

-Class D: 1.61

-Class E: 1.20

Table 3 Cost index for manufacturing plants of EC technology

Plant Subnetworks	Market Maturity	Business Model	Plant Archetype	Price Index Top	Price Index Non-Top
LIS	High	In-house	DED	75%	N/A
LIS	High	In-house	MULTI1	100%	125%
LIS	High	In-house	MULTI2	125%	125%
LIS	High	In-house	MICRO	N/A	N/A
LIS	High	Outsourced	DED	N/A	N/A
LIS	High	Outsourced	MULTI1	75-100%	125-150%
LIS	High	Outsourced	MULTI2	100-125%	125-150%
LIS	High	Outsourced	MICRO	N/A	N/A
LIS	Low	In-house	DED	75%	N/A
LIS	Low	In-house	MULTI1	100%	125%
LIS	Low	In-house	MULTI2	125%	125%
LIS	Low	In-house	MICRO	N/A	N/A
LIS	Low	Outsourced	DED	N/A	N/A
LIS	Low	Outsourced	MULTI1	125-200%	125-200%
LIS	Low	Outsourced	MULTI2	125-200%	125-200%
LIS	Low	Outsourced	MICRO	N/A	N/A

The reasoning of costing is aligned between the functions of strategic network design and Global Supply Finance. In principle, the logic is the following:

-LIS-High-In-house-DED: Core activity, cheaper compared to the baseline (Top).

-LIS-High-In-house-MULTI1: Baseline (Top), slightly expensive due to product complexity (non-top).

-LIS-High-In-house-MULTI2: Expensive due to significant but non-high volume products (top and non-top).

-LIS-High-In-house-MICRO: Not applicable. Not core activity.

A number of scenarios (20 in total) were explored with focus on creating clusters in order to increase the operations in FTA zones. The proposed solution is show in Figure 8.

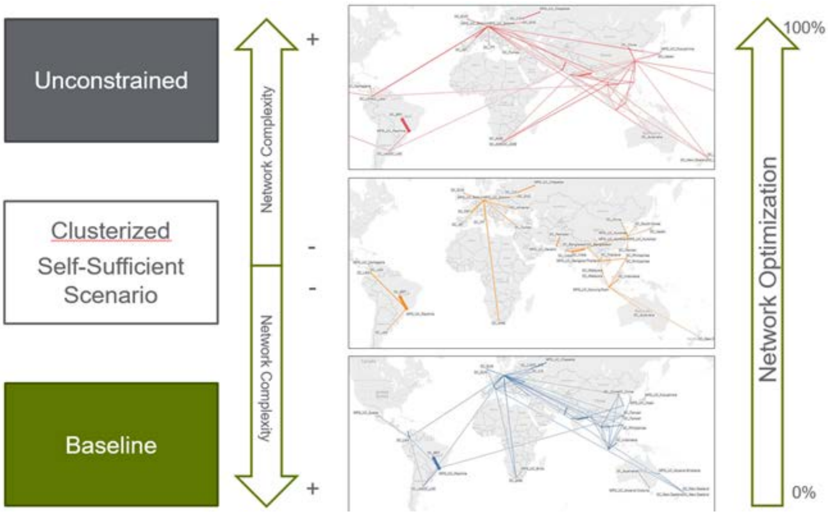

Figure 8 Proposed future network

The proposed idea is creating a clusterized self sufficient supply scheme by Free Trade Area or big geographical cluster with no more than two plants per cluster. This resulted in proposing a reduction of operations in 10 sites out of 30 and increased operations in others who will absorb the affected volumes. The overall estimated benefits of the approach are quantitatively the reduction of safety stock, idle capacity, fixed cost, duty cost and production cost and qualitatively the 40% less supply routes of UC, the overall network complexity elimination and the operational complexity reduction. In terms of cost split, the benefits are shown in Table 6.

Using advanced analytics tools (Supply Chain Guru, Tableau) in that type of assessments occurred the following benefits:

-Realistic representation of supply chain networks and ability to develop and run scenarios in reasonable time

-Effective communication to management. Project team was able to adjust graphs and analysis in a dynamic way, based on the discussions of the meeting.

-Ability to manage large set of data in an effective way

Table 4 Quantitative benefits of selected scenarios

Yearly production cost	-5%
Yearly Duty Cost	-12%
Yearly transportation cost	+3%
Yearly inventory holding cost	Neglectable

Limitations of the study include that this is a strategy work. Therefore, some of the estimations come from professional judgement of different functions. Planting costing might be different when it comes to procurement cycle because plant capabilities and market conditions need to be taken into consideration. The transition cost is also something that needs to be plugged into the overall business case. Another limitation is that this cost index is developed based on a specific production technology and using input from a specific project. Someone could deploy it to different technologies and make it more general, as a future research direction.

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