A Model for determining Industry Clusters portfolio of the Natural Gas Value Chain based on Industrial Clusters Structure (ICS) analysis

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Following globalization and intensifying the competition in the business environment, most of businesses are looking for competitive advantages. One way to achieve this goal is to form industrial clusters. In this paper, an screening model is introduced for determining industry clusters portfolio of the natural gas value chain. The model uses Industrial Clusters Structures (ICS), and develops a sequential filters-based technique to select the portfolio. At first phase, all products of natural gas value chain and their industrial clusters are identified. Next, on the basis of forming criteria of industrial clusters, high potential products to form a cluster are recognized. Then, they are evaluated and filtered based on a techno-economy and environmental feasibility study. Finally, the candidate products to form industrial cluster of natural gas are specified. In accordance with the natural gas experts opinions, a Nominal Group Technique (NGT) has been conducted to demonstrate the validity of the model. Moreover, the application of the proposed model is implemented in a real case extracted from Iran petrochemical industry. We believe that using the proposed model helps the relevant analysts to make decisions in most productive manner.

keywords: *Natural gas, Value chain, Industry cluster, Industrial clusters structures.*

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1. INTRODUCTION

A business or industry cluster, as popularized by Porter [1], can take multiple forms depending on the depth and complexity, but majority clusters include: companies of a ready product or service of one industry or aligned industries, suppliers, financial institutions. Such clusters affect competition among businesses in three ways: by increasing productivity of the companies in the cluster, by driving innovation in the field and by stimulating businesses in the field. A cluster thus is a grouping of institutions/firms in a geographic proximity that leads to positive impact on the economy of the cluster and their growth.

A value chain is a series of events that takes a raw material and with each step adds value to it. Global interest in the application of natural gas in production and transportation has grown dramatically. Many technological solutions are currently considered on the market or in development, that address the challenge and opportunity of natural gas. The natural gas value chain is from the supply to end-consumers through natural gas pipelines and the electrical systems value chain, i.e., power generation and transmission in an integrated way. Fig. 1 gives a brief description of different elements of oil and gas value chain [2].

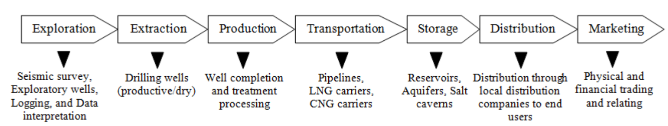

Fig. 1. Oil and Gas Value Chain

2. INDUSTRY CLUSTERS

Clusters are groups of inter-related industries that drive wealth creation in a region, primarily through export of goods and services. The use of clusters as a descriptive tool for regional economic relationships provides a richer, more meaningful representation of local industry drivers and regional dynamics than the traditional methods. An industry cluster is different from the classic definition of industry sectors, because it represents the entire value chain of a broadly defined industry from suppliers

Table 1. Definitions of the Term: "Industry Cluster

Reference	Definitions / Comments
Sheffi [4]	He has identified a number of strengths linked to logistics clusters. For example, logistics jobs are mostly local and place-based and hence, are not easily replaced by offshore jobs. Moreover, logistics clusters provide opportunities to train and develop skilled workforce internally. Furthermore, logistics services serve diverse industries and as a result, are more resilient to the recession shocks.
Hossain et.al. [5]	The wind power cluster seems a promising regional undertaking.,There is already heavy industry and its supporting business know-how in the case area, as well as required infrastructure. It can also be said that the case area already has wind power tradition. The wind power capacity of the case area is remarkable in,the domestic scale. Besides the conventional,energy sources, renewable energy sources including wind power play a vital role in satisfying the energy demand.
Sonobe and Otsuka [6]	An industrial cluster is a geographical concentration or localization of enterprises producing similar or closely related goods in a small area.
Rosenfeld, [7]	In its broadest sense, a cluster is defined by systemic relationships among firms and organizations in a general region based on common needs for nearby goods and knowledge.
Brenner [8]	A,local industrial cluster is an industrial agglomeration that is caused by,local self-augmenting processes.
Ketels [9]	Clusters are groups of companies and institutions co-located in a specific geographic region and linked by interdependencies in providing a related group of products and/or services.
Crouch and,Farrell [10]	The more general concept of cluster suggests a tendency for firms in similar types of business to locate close together.
van den Berg,,Braun and van,Winden [11]	The popular term cluster is most closely related to local or regional dimension of networks. Most definitions share the notion of clusters as localized networks of specialized organizations, whose production processes are closely linked through the exchange of goods, services and/ or knowledge.
Hill and,Brennan [12]	An industrial cluster is a geographic concentration of competitive firms or establishments in the same industry that have close buy-sell relationships with other industries in the region, use common technologies or share a specialized labor pool.
Roelandt and,den Hertog, [13]	Industrial clusters can be characterized as networks of producers of strongly interdependent firms (including specialized suppliers) linked each other in a value-adding production chain.
Simmie and,Sennett [14]	They define an innovative cluster as a large number of interconnected industrial and/ or service companies having a high degree of collaboration, typically through a supply chain, and operating under the same market conditions.
Porter [1]	Industrial clusters encompass an array of linked industries and other entities important to competition. Clusters also often extend downstream to channels and customers and laterally to manufacturers of complementary products and to companies in industries related by skills, technologies, or common inputs. Finally, many clusters include governmental and other institutions.
Swann and,Prevezer [15]	An industrial cluster means a large group of firms in related industries at a particular location.
Enright [16]	A regional cluster is an,industrial cluster in which member firms are in close proximity to each other
Swann and,Prevezer [17]	Industrial clusters are defined as groups of firms within one industry based in one geographical area.
Doeringer and,Terkla [18]	Industrial clusters are,geographical concentrations of industries that gain performance advantages,through co-location.
Maillat [19]	An 'innovative milieu' is a "complex" which is capable of initiating a synergetic process an organization, a complex system made up of economic and technological interdependencies a coherent whole in height which a territorial production system, a technical culture, and protagonists are linked.

to end products, including supporting services and specialized infrastructure. Clustered industries are geographically concentrated and inter-connected by the flow of goods and services, which is stronger than the flow linking them to the rest of the economy [3]. Defining the characteristics of a cluster, similar to giving a single, unique and correct definition,
is not an exact science. Although different authors emphasize on different characteristics, they do however agree on the main dimensions (see Table 1).

We name the hierarchical structure of industry clusters of a parent product as "Industrial Clusters Structure (ICS)" (see Fig. 2, a schematic view of ICS). ICS for an assumed product includes the various hierarchical derivatives from that product. For instance, in Fig. 2, products A, B, and C are derived from parent product; B1, B2, and B3 are derived from product B; and so on. It should be noted that the entire products of an ICS are considered as options to be involved in the industry cluster.

3. NATURAL GAS ICS

In this section, the natural gas ICS, its derivatives, and their ICSs are presented. For this purpose, Fig. 3 to 11 are portrayed. Fig. 3 presents the natural gas ICS, which includes 17 hierarchical derivatives; eight of 17 (Ammonia, Methanol, Acetylene, Carbon

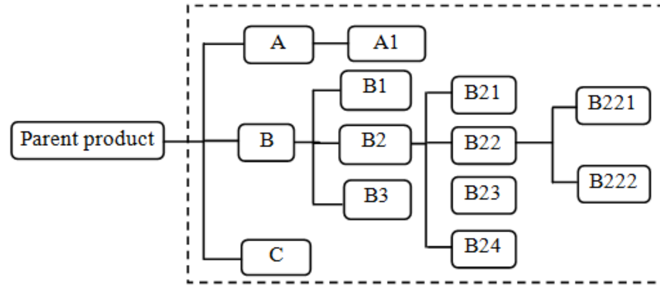

Fig. 2. The ICS for an assumed parent product

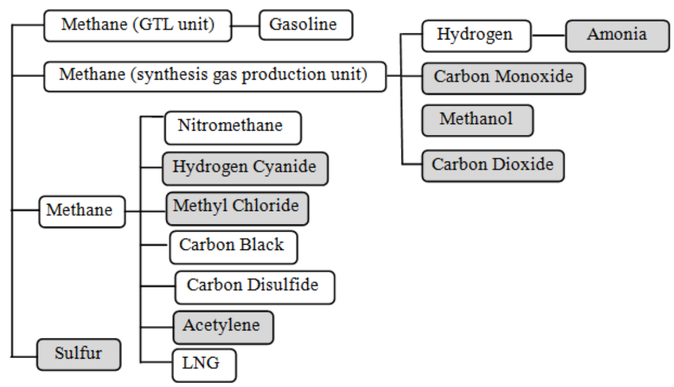

Fig. 3. Natural gas ICS

Monoxide, Carbon Dioxide, Hydrogen Cyanide, Methyl Chloride, and Sulfur) have own related hierarchical derivatives. Fig. 4 to 11 show the ICS for these products, respectively.

4. THE PROPOSED MODEL

The proposed model simply includes four phases as follows:

- Phase A: Determining the criteria.
- Phase B: Gathering the data.
- Phase C: Processing the clusters data.
- Phase D: Screening the clusters.

Determining criteria: Many criteria influence the filtering clusters. These are elements of a set namely CFC (Cluster Filtering Criteria). Some major criteria include (but not limited to) marketing indexes, consumption trend (inner, or out of the country), social or political aspects, and risks. According to [3] CFC may include geographical scope, proximity, size, breadth, typology, life-cycle, specialization, and depth (see Table 2). In general, there are two types of criteria: Cost and Benefit. A cluster with more value of a benefit criterion is more important; e.g. reliability, growth, and opportunity. Conversely, a cluster with less value of a cost criterion is more important; e.g. threat, complexity, and instability.

Gathering data: At the first stage of this phase, data for the selected criteria should be gathered, that may be objective or subjective. Objective data are extracted from historical records; while subjective ones are received from expert opinions. In the case of subjective data, a 7-points scale is recommended as: extremely week, very low, low, moderate, high, very high, and extremely strong. In the proposed model, subjective data must be quantified; this is the second stage of the current phase. Table 3 exhibits the recommended scores to quantify subjective data.

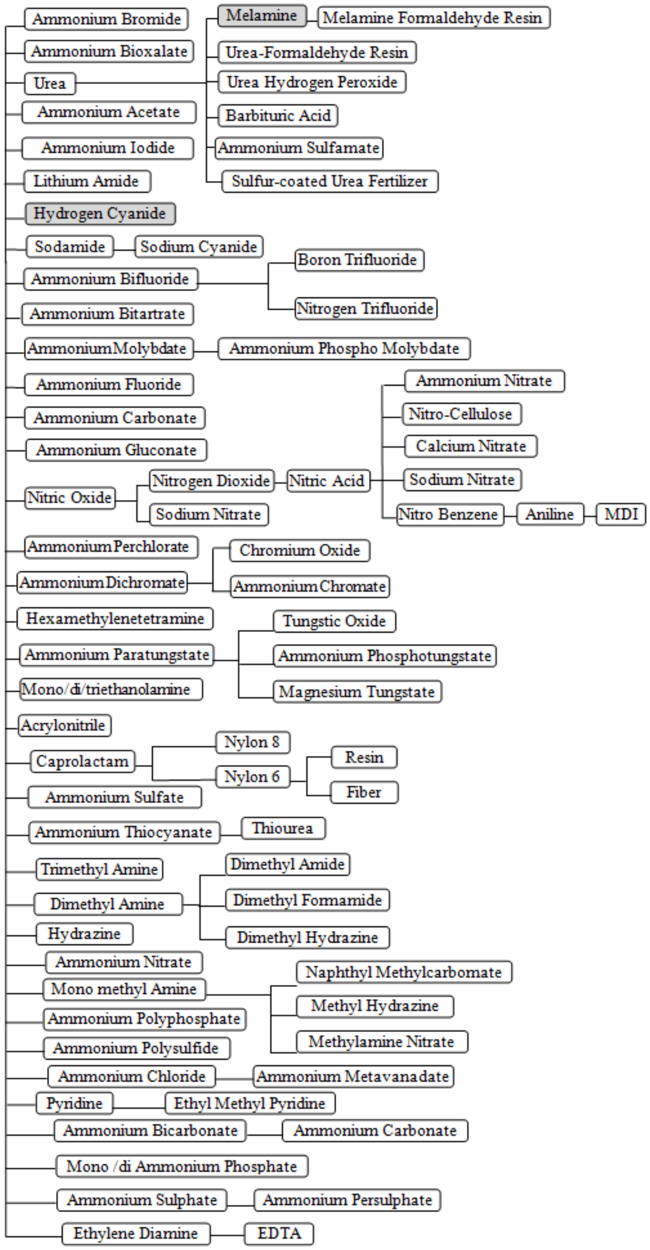

Fig. 4. Ammonia ICS

Processing clusters data: This phase is the calculation core of the model. Output of the previous phase is raw data which have to be processed to get real data. Fig. 12.a presents a schematic ICS including products 1,..,T. In regards with criterion j, to apply the impact of branch product k on product i, a coefficient α_{ijk} is considered as Equation (1). This equation means the real data of a cluster is equal to its raw data plus summation of a ratio of real data of its direct successor clusters.

$$v_{ij} = d_{ij} + \sum_{k=1}^{T} \alpha_{ikj} \times v_{kj} \quad \forall i \in ICS \quad \forall j \in CFC \tag{1}$$

where

d_{ij}: Raw data for criterion j on industry cluster i

v_{ij}: Real data for criterion j on industry cluster i

α_{ikj}: Influence coefficient of criterion j from industry cluster k into industry cluster i

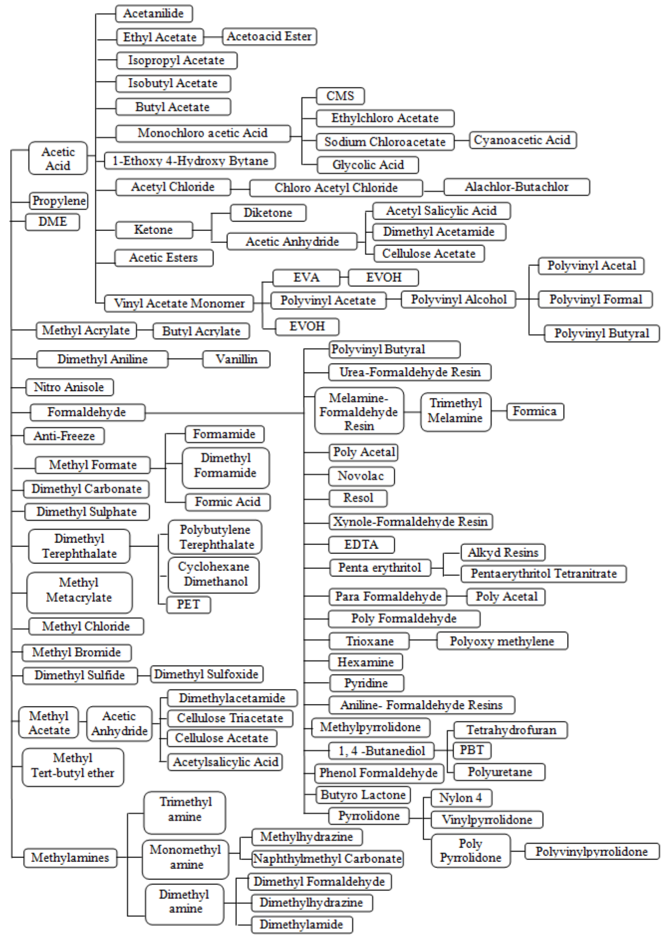

Fig. 5. Methanol ICS

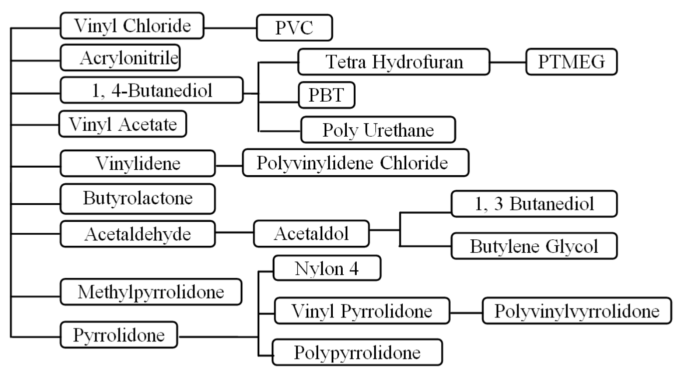

Fig. 6. Acetylene ICS

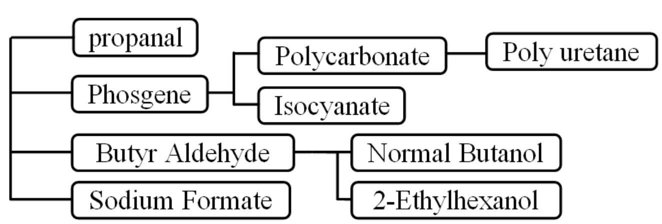

Fig. 7. Carbon Monoxide ICS

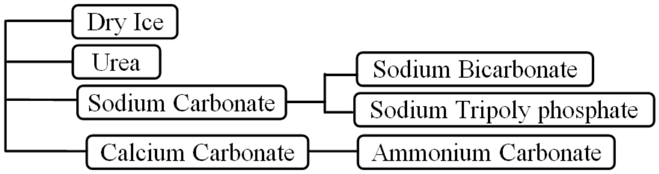

Fig. 8. Carbon Dioxide ICS

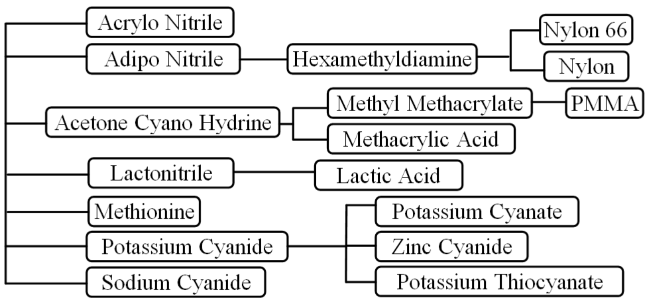

Fig. 9. Hydrogen Cyanide ICS

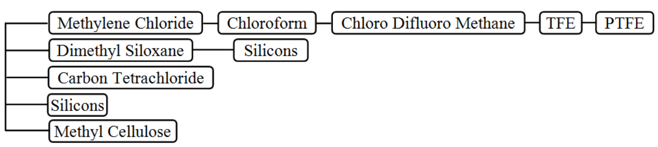

Fig. 10. Methyl Chloride ICS

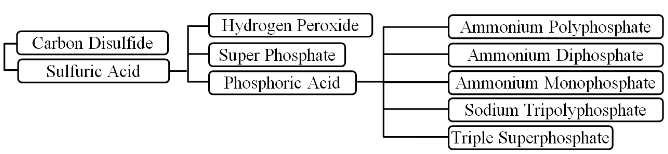

Fig. 11. Sulfur ICS

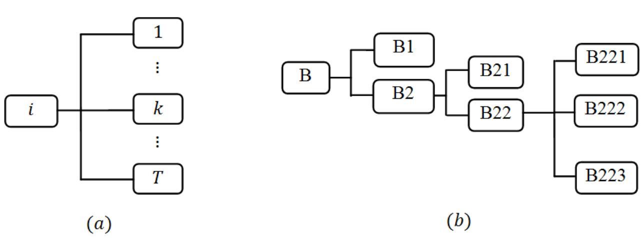

Fig. 12. (a): A simple Schematic ISC; (b): An example ISC

For example, for a given criterion, assume raw data of boxes in Fig. 12.b are $d_B = 0.05, d_B1 = 1.1, d_B2 = 0.1, d_{B21} = 0.5$, $d_{B22} = 0.04$, $d_{B221} = 0.06$, $d_{B222} = 0.0$, and $d_{B223} = 0.15$. In addition, assume influence coefficient of the criterion is 0.4 for the entire relationships. Hence, the real data of the boxes would be:

Table 2. Main characteristics of an industry cluster

Criteria	Definition
Geographical Scope	This criterion indicates the geographical scope of an industry cluster.
Proximity	Proximity or geographical co-location of firms is another characteristic of a cluster. Clusters exist, grow and develop because companies and other cluster participants benefit from their concentration, proximity and interdependence, which might not be possible to such extent when they locate outside the cluster or operate independently.
Size	This criterion refers that some clusters consist of small and medium enterprises; others involve large and small firms.
Breadth	The breath is defined by the range of industries related by horizontal relationships.
Typology	For the last several years, the researchers have used the following categories to characterize the state of development of clusters: working, latent, potential, policy driven, and wishful thinking [20].
Life cycle	Life cycle concerns four different stages: embryonic,stage, growth stage, maturity, and decay.
Specialization	It is about specialization in a single industry or in,a majority of the individual industries comprising the cluster.
Depth	The depth refers to the range of industries related by vertical relationships.

Table 3. The scale in quantifying subjective data

Descriptor	Description (from the view of the given criteria)	Score
Extremely weak	Industry cluster is extremely weak	0
Very Low	There are very minor potential aspects in industry cluster	10
Low	Low potential aspects could be considered for industry cluster	30
Moderate	The industry cluster circumstance is so-so	50
High	High potential aspects could be considered for industry cluster	70
Very High	There are very major potential aspects in industry cluster	90
Extremely strong	Industry cluster is extremely maturated	100

$$v_{B1} = d_{B1} = 1.1$$
$$v_{B21} = d_{B21} = 0.5$$
$$v_{B221} = d_{B221} = 0.06$$
$$v_{B222} = d_{B222} = 0.0$$
$$v_{B223} = d_{B223} = 0.15$$
$$v_{B22} = d_{B2} + \alpha_{B22B221} \times v_{B221} + \alpha_{B22B222} \times v_{B222} + \alpha_{B22B223} \times v_{B223} = 0.04 + 0.4 \times 0.06 + 0.4 \times 0.0 + 0.4 \times 0.15 = 0.124$$
$$v_{B2} = d_{B2} + \alpha_{B2B21} \times v_{B21} + \alpha_{B2B22} \times v_{B22} = 0.1 + 0.4 \times 0.5 + 0.4 \times 0.124 = 0.3496$$
$$v_B = d_B + \alpha_{B,B1} \times v_{B21} + \alpha_{B,B2} \times v_{B22} = 0.5 + 0.4 \times 1.1 + 0.4 \times 0.3496 = 0.62984$$

Screening clusters: The output of the previous phase is a cluster list which contains real data for the selected criteria. In the current phase, we should screen the list. At the first stage, a DELPHI technique should be executed to rank the criteria. At the second stage, an acceptance level should be determined for each criterion. The analysts, with regards to their skills and knowledge, can set acceptance levels. All the same, the model recommends a zonal-based approach to set the levels

As it is shown in Fig. 13, the problem falls into one of the four quadrants. Two factors specify these quadrants: "environmental uncertainty level" and "supports logistics". The former one refers to economical political stability, tolerances of decision-makers, risks, etc. The latter one stands for resource availability (budget, manpower, technology, information, and material),

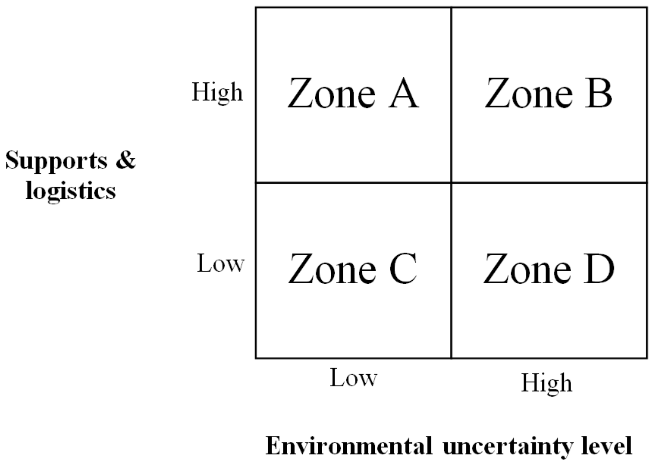

Fig. 13. The zonal-based approach to set the acceptance levels

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Inputs: List of clusters, Real data, Criteria Acceptance Levels (AL), Ranking of criteria from CFC
Output: Reminded clusters as the final list

Method:
{
    R =1
    Repeat until the entire criteria are considered
        {
            Designate the criterion with rank R as j
            For positive criteria, from list, eliminate clusters i in which v_ij ≤ AL_j
            For negative criteria, from list, eliminate clusters i in which v_ij ≥ AL_j
            R = R + 1
        }
}
```

Fig. 14. The screening pseudo code

management supports, procurement plans, etc. Regarding Fig. 13, acceptance levels should be set as:.

• Zone A: 20% average of real data for positive criteria, and 180% average of real data for negative criteria.

• Zone B: 50% average of real data for positive criteria, and 150% average of real data for negative criteria.

• Zone C: 50% average of real data for positive criteria, and 150% average of real data for negative criteria.

• Zone D: 80% average of real data for positive criteria, and 120% average of real data for negative criteria.

A given cluster will be removed from the list, if its real data is not under the related acceptance level. The third stage, screening, includes main task of the current phase. Here, a preemptive method is considered to screen the clusters. Fig. 14 indicates the pseudo code of this method in which clusters are lexicographically screened.

5. VALIDATION OF THE MODEL

A Nominal Group Technique (NGT) has been carried out as a validation of the proposed model. Ten experts with skills in the natural gas related disciplines and decision-making methods gave their opinions. Experts lasted almost 13 to 15.5 hours in the NGT meetings. Initially, a complete description of the model was presented to the experts; then they evaluated it with a score from 0 to 10, also taking into account its effectiveness and usability. Furthermore, the experts said the reasons for their judgments. The average of the scores is 8.3, which is considerably good. The main notes stated by the experts are:

- Fairly usable and comprehensive.
- The model will be flexibly customized to apply in various scales.
- It is required to provide a software package including calculations.

A. The case study

The proposed model has been used for a real case extracted from Iran petrochemical industry. An Iranian big chemical private company aims at developing its activities to produce Acetylene and its derivatives (see Fig. 6). In order to make decision, the company senior managers agree to take five criteria into account as "International annual growth", "Inner annual consumption", "Production technological complexity", "Production resource accessibility", and "HSE (Health, Safety, and Environment) regulation limitations". Data for the two former criteria were gathered through the recent research documents such as [21–25], valid internet databases such as [26–36], and government's sectors information systems such as [35, 37–39]. Further, for the three latter criteria, a Delphi technique was run. For this purpose, two meetings have been held with a total of 5 experts. Of course, the project analysts did not have access to the recorded data for two products: Acetaldol and Polypyrrolidone; in turn for this fact, based on a worst case analysis, the minimum and the maximum data of the other derivatives were considered for positive and negative aspects, respectively. The results are presented in Table 4. It should be noted that the qualitative terms have been quantified by means of the Table 3 guidance.

For the purpose of executing the third phase of the model, i.e. processing clusters data, the influence coefficient for the each criterion was considered as a fixed number for the entire links through the Acetylene ICS. These coefficients are 0.3, 0.3, 0.05, 0.05, and 0.1 for International annual growth, Inner annual consumption, Production technological complexity, Production resource accessibility, and HSE regulation limitations, respectively. In continuation, the calculations to get real data were made. The results are presented in Table 5

A DELPHI technique was executed to rank the criteria. Additionally, according to Fig. 13, quadrant of the project was determined as Zone B, therefore acceptance levels were set as 50% average of real data for international annual growth, inner annual consumption, and production resource accessibility, and 150% average of real data for production technological complexity, and HSE regulation limitations. Useful information about the criteria is presented in Table 6.

At the final stage, clusters should be screened. International annual growth is the first filter in which Acrylonitrile, Vinyl Acetate, and Polypyrrolidone are removed from the list. Regarding the second and third filters, i.e. production technological complexity HSE regulation limitations, no products are removed, because the entire real data are less than the acceptance levels. The fourth filter, inner annual consumption, causes removing many Acetylene derivatives, except Acetylene, Vinyl Chloride, PVC, 1, 4-Butanediol, and Poly Urethane. Finally, production resource accessibility, by the fifth rank, has no effect on these derivatives. Consequently, Acetylene, Vinyl Chloride, PVC, 1, 4-Butanediol, and Poly Urethane are the recommended products to invest and to establish industry clusters.

Table 4. Gathered data for the selected criteria in the case study

Production	International annual growth (percentages)	Inner annual consumption (1000 tons) (7-points scale)	Production technological complexity (7-points scale)	Production resource accessibility	HSE regulation limitations (7-points scale)
Acetylene	2.0	3.50	50	50	30
Vinyl Chloride	4.5	1.30	50	50	70
PVC	3.2	32.3	50	50	50
Acrylonitrile	2.0	7.20	90	50	30
1, 4-Butanediol	1.9	4.90	50	50	50
Tetra Hydrofuran	3.8	0.51	50	50	50
PTMEG	8.3	0.66	90	70	70
PBT	6.5	0.83	90	70	70
Poly Urethane	2.9	5.70	90	70	70
Vinyl Acetate	2.1	4.97	30	50	70
Vinylidene chloride	2.3	0.30	90	70	70
Polyvinylidene Chloride	5.9	1.80	50	50	30
Butyrolactone	7.0	0.38	70	70	50
Acetaldehyde	1.6	1.00	50	50	70
Acetaldol	1.6	0.04	90	50	70
1, 3 Butanediol	4.8	0.38	50	50	30
Butylene Glycol	5.0	0.38	70	50	70
Methylpyrrolidone	7.0	0.45	50	50	70
Pyrrolidone	6.0	0.04	90	70	70
Nylon 4	2.9	1.54	50	70	30
Vinyl Pyrrolidone	5.0	0.35	50	50	50
Polyvinylpyrrolidone	6.0	0.08	30	50	50
Polypyrrolidone	1.6	0.04	90	50	70

Table 5. Real data for the selected criteria in the case study

Production	International annual growth (percentages)	Inner annual consumption (1000 tons) (7-points scale)	Production technological complexity (7-points scale)	Production resource accessibility	HSE regulation limitations (7-points scale)
Acetylene	15.98	13.58	80.06	76.80	90.12
Vinyl Chloride	5.46	10.99	52.50	52.50	75.00
PVC	3.20	32.30	50.00	50.00	50.00
Acrylonitrile	2.00	7.20	90.00	50.00	30.00
1, 4-Butanediol	6.61	7.07	61.73	59.68	69.70
Tetra Hydrofuran	6.29	0.71	54.50	53.50	57.00
PTMEG	8.30	0.66	90.00	70.00	70.00
PBT	6.50	0.83	90.00	70.00	70.00
Poly Urethane	2.90	5.70	90.00	70.00	70.00
Vinyl Acetate	2.10	4.97	30.00	50.00	70.00
Vinylidene chloride	4.07	0.84	92.50	72.50	73.00
Polyvinylidene Chloride	5.90	1.80	50.00	50.00	30.00
Butyrolactone	7.00	0.38	70.00	70.00	50.00
Acetaldehyde	2.96	1.08	54.80	52.75	78.00
Acetaldol	4.54	0.27	96.00	55.00	80.00
1, 3 Butanediol	4.80	0.38	50.00	50.00	30.00
Butylene Glycol	5.00	0.38	70.00	50.00	70.00
Methylpyrrolidone	7.00	0.45	50.00	50.00	70.00
Pyrrolidone	9.39	0.63	99.58	78.63	85.50
Nylon 4	2.90	1.54	50.00	70.00	30.00
Vinyl Pyrrolidone	6.80	0.37	51.50	52.50	55.00
Polyvinylpyrrolidone	6.00	0.08	30.00	50.00	50.00
Polypyrrolidone	1.60	0.04	90.00	50.00	70.00

Table 6. Real data for the selected criteria in the case study

Criterion	International annual growth	Inner annual consumption	Production technological complexity	Production resource accessibility	HSE regulation limitations
Aspect	Positive	Positive	Negative	Positive	Negative
Data type	Objective	Objective	Subjective	Subjective	Subjective
Influence coefficient	0.3	0.3	0.05	0.05	0.1
Rank	1	4	2	5	3
Acceptance level	2.77	2.01	100.64	29.43	92.83

6. CONCLUSION

In this paper, in order to determine the valuable products in downstream value chain of natural gas, a mixed qualitative and quantitative procedure was developed, which has not been studied yet. Our main contribution is innovative method for computing real data, on a filter-based and zonal-based screening system in which techno-economy and environmental aspects could be applied. Application of the proposed model, in a case study extracted from Iran petrochemical industry, presented applicability and flexibility of the model.

This research in its process faces some limitations and the results are subject to those limitations. The most important limitation was inaccessibility to detailed information of production technology of those products and also vagueness of the estimated future demand. This research has an open new window to future research, which is to execute the proposed methodology for each of the eight defined value chain in this paper.

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