SIMULATION OF GOAL PROGRAMMING MODEL OF DIFFERENT PRIORITY STRUCTURES OF NIGERIAN PETROCHEMICAL INDUSTRY

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ABSTRACT

In this paper the goal programming (G.P.) model is applied to different priority structures to predict the structure of Nigerian downstream petrochemical industry. The primary aim is to be self sufficent in petrolchemicals through the selection of technologies that will minimize the total production cost and feedstock consumption. Therefore, the pre-emptive priority factors (P_{1i} *for* i - 1,...,m, P_2, P_3, P_4) in the multi-dimentional objective function of the G.P. are chosen to be in accordance with the long terms objective of satisfying the demand locally.

On the tested priority structures, it is deduced that maximum goal target is a function of cost coefficient and demand while minimum goal target is a function of cost coefficient, demand and priority factor. It is noted that for the same goal target, most of the selected technologies are identical except for a few chemicals, it is preferable either to shift to another process or to simply import the chemicals.

1. INTRODUCTION

Nigeria has ample oil resources, coal reserve and natural gas, but it depends largely on imported petrochemicals. The task at hand is to find a method for the sequential replacement of imported petrochemicals by local production. This necessitate the knowledge of interaction among the technical, economic and behavioural forces to determine the cost of industrial development in the long-run.

The petrochemical industry is a large interactive system which requires a model that can account for the different interactions among units. The units of this system interact by competing for raw materials, market and process technologies. Thus, if certain unit of the industry are examined in isolation, there is no guarantee that the conclusions reached will be significant when the performance of the overall system is of importance. In such a large interactive system, Stadtherr and Rudd[17] stated that the whole is not necessarily made more efficient if one unit is improved. In fact local inefficencies may be necessary if the overall system is to operate at maximum efficiency. Consequently, in this study, the performance of the system as a whole supersedes the local economics of individual units of the industry.

The downstream petrochemical industry can be assumed to be a system that takes the primary petrochemicals such as olefins, acetylene, benzene, toluene, xylenes and naphthalene from the upstream industry, and transforms them to petrochemical intermediates (acrylonitrile, acetaldehyde, alcohol, ester, etc.) and finished products (plastics, elastomers, synthetic fibres, etc.).

In Akinlade and Olabisi[1], it has been proved that goal programming is more effective to model the industry due to its ability to incorporate multiple objectives and goals which are invariably incompatible. The interaction of the technological and socio-politico-economic forces in Nigeria dictates a number of incompatible objectives that must be incorporated in a realistic model of the Nigerian petrochemical industry. The model incorporates the fact that a chemical can be produced from two or more technology routes, each involving different combinations of feedstocks and co-products, and the model is driven by endogenous/exogenous demand for chemicals and the availability of the appropriate technologies.

In Akinlade and Olabisi[1], the G.P. model is applied to equal priority (i.e. the goals are equally

probable), it is now applied to different priority structures taken into consideration the long terms objectives/goals. As earlier conjectured, the primary goal is to minimise the importation of petrochemicals as such as possible by investing highly on local production of petrochemicals. Meeting the local demand is apparently the highest priority followed by the production cost of the technology to produce the petrochemical. Due to limited supply of primary petrochemicals, it will be in the interest of Nigerian economy to give a high priority to the goal that minimizes the total feedstock consumption. This combination of attainment of minimum production cost and minimum feedstock consumption to meet demand, will be paramount in the selection of the best available technologies subject to specific supply/ demand patterns through the use of G.P. model.

2. FORMULATION OF THE MODEL

The downstream petrochemical industry is viewed as a system of M chemical transformations and L fabrication technologies that produce or consume N materials. Each of the N materials is a potential input to the industry, and/or an intermediate produced and consumed within the industry, and/or a final product (fabricated or unfabricated) from the industry. The processes involve chemical and/or physical transformations and therefore are defined by their specific material balance. The material interactions among processes are assumed to be linear.

2.1 GOAL CONSTRAINTS

2.1.1. DEMAND GOALS

The first goal is the one which minimizes the overproduction of petrochemicals. In linear programming (L.P.) technique, there arises the problem of some technology routes overproducing in excess of available demand. This weakness on the part of L.P. may be overcome by the introduction of G.P. which tries to minimize the deviations of production levels from specified target.

The goals can be mathematically written as: Material balance for each item at steady state in the industry is given as:

Amount of local feed i Underage of material	±	Amount of unfabricated material i transformed	Overage of imaterial i	=	Amount of ± fabricated material i transformed Demand goal of material i	+	Amount of Imported material i	+

$$F_i + \sum_{j=1}^{M} a_{ij}X_j + \sum_{k=1}^{L} b_{ik}Y_k + I_i + U_{1i} - V_{1i} = G_{1i} \quad \text{for } i = 1,\ldots,N \qquad (1)$$

But we know that demand is the lower bond for the goal constraints, hence G_{1i} cannot be underachived, therefore $U_{1i} = 0$ for i = 1,...,N.

Equation (1) becomes

$$F_i + \sum_{j=1}^{M} a_{ij}X_j + \sum_{k=1}^{L} b_{ik}Y_k + I_i - V_{1i} = G_{1i} \quad \text{for } i = 1,\ldots,N \qquad (2)$$

Where a_{ij}/b_{ik} is the amount of unfabricated/fabricated material i per unit of chemical trasformation j/fabrication technology k. Positive if produced, negative if consumed, zero if neither produced nor consumed.

X_j is the level of operation of process j.
Y_k is the level of operation of process k.
I_i is the amount of imported material i.

2.1.2 LOCAL COST GOAL

The satisfaction of the demand of petrochemicals in Nigeria will be dependent for some time on the mixture of importation and local production of petrochemicals. In previous mixed integer programming (MIP) model by Jimenez et al [8, 9,10], they lumped together the prices of imported materials in the total production costs. This attempt will lead to an appreciable error for imported end products which would no longer undergo any transformation in the industry.

The second goal is therefore the minimization of deviation from local costs for the production of petrochemicals. The local costs consist of local feedstock costs and technology costs. The goal is stated as follows:

Cost of local feeds	+	Technology cost of materials	Underage + of local cost	Overage -of local cost	=	Local cost goal

$$\sum_{i=1}^{N} PiFi + \sum_{j=1}^{M} CjXj + \sum_{k=1}^{L} CkYk + U2 - V2 = G2 \qquad (3)$$

2.1.3 Imported Cost Goal

The third goal is the minimization of deviation from imported costs for the procurement of petrochemicals. The imported cost consist of imported petrochemicals' costs to meet the local demand. The goal is stated below:

Cost of imported materials	+	Underage of imported cost	-	Overage of imported cost	=	Imported cost goal

$$\sum_{i=1}^{N} BiIi + U3 - V3 = G3 \qquad (4)$$

2.1.4 Feedstock Consumption

The fourth goal is the minimization of deviation from feedstock consumption. The minimum feedstock criterion employed in the previous work on L.P. model by Stadtherr and Rudd [18] is modified to reflect the contribution of nitrogen, oxygen and chlorine atoms in addition to carbon atoms to the feedstock consumption. It is our contention that the inclusion of carbon atoms and the exclusion of others is limiting and may result in erroneous process selection. This makes the selected technology routes an efficient feedstock utilization. The goal is as stated below:

Amount of feedstock consumed	+	Underage of feedstock goal	Overage of feedstock	=	Feedstock consumption goal

$$\sum_{i=1}^{N} eiFi + U4 - V4 = G4 \qquad (5)$$

Where *ei* is the ration of the contribution of carbon, oxygen, nitrogen and chlorine atoms to the feedstock i.

Cj is the unit operating cost for chemical transformation j.

Ck is the unit operating cost for fabrication technology k.

Pi is the local unit price for material i.

Bi is the imported unit price for material i.

2.2 Resource Constraints

Local feedstock *Fi* used cannot exceed feedstock *Si* supplied

$$Fi \leq Si \qquad i = 1,2,...,N \qquad (6)$$

Each chemical transformation cannot exceed the capacity, *Uj*, for the given transformation j.

$$Xj \leq Uj \qquad j = 1,2,...,M \qquad (7)$$

Likewise for fabrication technology

$$Yk \leq Uk \qquad k = 1,2,...,L \qquad (8)$$

$$Fi \geq 0,\ Xj \geq 0,\ Yk \geq 0,\ Ii \geq 0, \qquad (9)$$

2.3 Multi-dimensional Objective Function

In the demand goals in order to avoid undue emphasis being placed on those demand levels with goals of greatest values, we minimize the percentage deviations rather than absolute deviations between the production levels and their goal levels (demand levels).

i.e. Minimize $\sum_{i=1} \frac{Vli}{Di} \times 100$ for i = 1,...,M

In the second and third goals, minimization of costs is envisaged, then it is imperative to attach zero weight to underages of these goals and then minimize overages *V2* and *V3*. Also in the fourth goal, efficient feedstock utilization is needed, therefore zero weight is attached to its underage,

and its overage $V4$ is minimized.

The multi-dimentional objective function for the G.P. model is as stated below.

$$\text{Minimize } \sum_{i=1}^{N} P_{1i} \frac{V_{-1i}}{Di} \times 100 + P_2V_2 + P_3V_3 + P_4V_4 \quad (10)$$

Where P_{1i} for $i = 1,...,N, P_2, P_3$ and P_4 are pre-emptive priority factors. The priority structure for petrochemical development is the one that will suit the country's urge for self-sufficiency in petrochemicals' production.

The above objective function together with the goal constraints and resource constraints in equations (2)-(9) form a goal programming problem which can be solved via revised simplex method to obtain *Xj, Yk, Fi, Ii* under different scenarios.

3. CONSTRUCTION OF THE MODEL

The first step in constructing the model formulated above is the selection of chemicals/polymers, chemical transformations and fabrication technologies which constitute the model. Table 1 shows the unfabricated/fabricated materials included in the model. The selection of the material is based on the demand in Nigeria and those considered accessible for development in Nigeria. Table 1 also shows the function of each selected materials, that is, whether it serves as a primary input, final output, intermediate or combination of the above. For each material selected, the model includes chemical transformation and fabrication technologies currently used to manufcature the material. Table 2 lists the chemical transformations/fabrication technologies accounted for by the model.

The heart of the model is the technology matrix which is composed of the input-output co-efficients, a_{ij}'s and a_{ik}'s. For this purpose, yield data for each chemical transformation/fabrication technology are required. Information on the input-output coefficients which constitute the technology matrix is obtained from the materials on petrochemical technology proprietary to Shanahan valley Associates [15] and others [3, 4, 5, 6, 7. 14]. The technology matrix is given elsewhere [2].

Needed for the model are supply, demand and capacity data. Since the industry must compete for its feedstocks and market, supply and demand data are best determined by functional aggregate studies[15]. In this work, however, the supply and demand data used are estimated using observed values of production and observed usage patterns. We assumed except when supply is perturbed to see its effect on the industry, that the upstream industry could supply the primary petrochemicals that are needed by the downstream industry. Because of this, we only constraint the local feedstock, F_i, to be greater or equal to zero.

The demand data are obtained from Manufacturers' Association of Nigeria [11], National Oil and Chemical Marketing Company Limited [12] and Nigerian National Petroleum Corporation[13]. The projected demand for the selected petrochemicals are given in Akinlade[2]. Nameplate capacity is given to manufacturing route. The nameplate capacities given to the plants in operation or being planned for by the government are the ones used in the computation as long as they exceed the demand. The remaining nameplate capacities are assigned to be more than the demand of the chemical to be produced through the technology route. The nameplate capacity and the prices for local and imported petrochemicals are given in Akinlade[2]

Needed to complete the goal programming model is the weight fraction of carbon, oxygen, nitrogen and chlorine in a unit of feedstock i.

4. SETS A AND B

The G.P. model is applied to two sets of different priority structures as follows:

Set A is where the priority structures are assigned in such a manner that the global minimum of imported costs goal can be exceeded when the model selects technologies to produce chemicals locally.

Set B is where the priority structures are assigned in such as a way that the global minimum of imported costs goal cannot be exceeded when technologies are selected to manufacture petrochemicals locally.

The global minimum of the imported costs goal is the minimum amount to expend on the importation of petrochemicals which are found by the model to be unviable for local production when equal priority of 1 is assigned to all goals. The global minimum of imported costs goal for the projected demand is $\$5.04 \times 10^7$. This figure is further confirmed to be global minimum when none of the tested priority structures in sets A and B gives a lower minimum for imported cost goal.

4.1 Set A

Case A : The demand goals, local cost goal and feedstock consumption goal are assigned the highest priority of 1.0×10^9 and the imported cost goal is given a priority of 1.0 (i.e. $P_1 = P_2 = P_4 = 1.0 \times 10^9$, $P_3 = 1.0$).

Case B : The demand goals and local cost goal are given the highest priority while the feedstock consumption is given a lower priority and the imported cost goal the least priority (i.e. $P_1 = P_2 = 1.0 \times 10^9$, $P_4 = 1.0 \times 10^5$, $P_3 = 1\ 0$).

Case C : The demand goals and the feedstock consumption goal are assigned the highest priority, while the local cost goal cost is given a lower priority and imported costs goal the least priority (i.e. $P_1 = P_4 = 1.0 \times 10^9$, $P_2 = 1.0 \times 10^5$, $P_3 = 1.0$)

4.2 Set B.

Case E : The demand goals, local cost goal and imported cost goal are given the highest priority of 10^9 while the feedstock consumption is given the least priority of 1.0 (i.e. $P_1 = P_2 = P_3 = 1.0 \times 10^9$, $P_4 = 1.0$).

Case F : The demand goals, feedstock consumption goal and imported cost goal are assigned the highest priority of 1.0×10^9 while the least priority of 1.0 is given to the local cost goal (i.e. $P_1 = P_3 = P_4 = 1.0 \times 10^9$, $P_2 = 1.0$).

Case G : The demand goal, the local cost goal and the imported cost goal are given the priority of 10^9 while the feedstock consumption is given a priority of 10^5 (i.e. $P_1 = P_2 = P_3 = 10^9$, $P_4 = 10^5$).

These two priority structures are applied to the model when local cost goal G_2 and feedstock consumption goal G_4 are at their maxima and imported cost goal G_3 is at zero. The minima of imported cost goal and feedstock consumption goal to satisfy the demand under the prevailing local costs are determined. Parts of results for the cases in set A and set B are given in tables 3 and 4 respectively.

In tables 3 and 4, the column with 'PN' relates to the process number per chemical which corresponds to the number given in the list of technology in table 2. Also, the usage level of a chemical in a particular technology route is defined as the ratio of the production level of the specific technology, Xj to the demand level of the specific chemical, Di.

i.e. Usage level, $U\,Lij = \frac{Xj}{Di}$

Some observations are worth mentioning in the results of set A.

(a) In cases A, B and C, the model selects oxidation of ethanol's route for acetaldehyde's production.

(b) In both cases A and B, the acetic acid's by-product from terephthalic acid's production via acetaldehyde's process is enough to meet the needed demand for acetic acid. But for case C more acetic acid is neded and this is met through the air oxidation of acetaldehyde.

(c) In cases A and B, the acetone obtained as by-product from the production of hydrogen peroxide makes it unnecessary to set up a plant for acetone to satisfy the given demand.

(d) The model advises us against production of cumene in case B while it favours its production for other cases via reaction of benezene and propylene's process.

(e) Under the tested priority structures, most of the selected technologies to produce chemicals are identical except for a few chemicals where the shift in technology is noted like in phenol's production in case A, the model prefers dehydrochlorination of chlorobenzene's route while it prefers sulphonation of benzene's process for cases B and C.

(f) The model opts for the importation of a few chemicals like cyclohexane, isophthalic acid and cumene in case B, menthanol in case C, and toluene diamine in case A.

(g) Methyl ethyl ketone (MEK) demand is met from its by-product obtained from the process which produces allyl alcohol via acrolein and s-butanol in all the three cases.

(h) Only sixty four percent of the demand of the urea is met in case A, the remaining demand is satisfied through importation while in cases B and C the demand is fully met via reaction of carbon dioxide and ammonia.

(i) In the model industry, polymethyl methacrylate is produced via batch casting while polypropylene's production is by solution process.

(j) In cases A, B and C, G_3 is overachieved by $\$2.74 \times 10^8$, $\$6.99 \times 10^8$, and $\$7.60 \times 10^8$ respectively. G_4 is underachieved in cases A, B and C by 9.35×10^5, 1.36×10^6, 4.61×10^5 metric tonnes respectively.

Some observations need to be highlighted in the result of set B.

(a) In cases E and G, acetaldehyde is to be produced via one step oxidation of athylene while in case F oxidation of ethanol is preferable. High usage level for acetaldehyde is needed in case G due to its requirement in terephthalic acid's (crude) production.

(b) Large quantity of acetic acid produced as by-product in the process that produced terephthalic acid (crude) is responsible for the very low usage level in case G.

(c) Just as in cases A and B in set A, the model finds it unnecessary to set up plants for the production of acetone. This is due to acetone obtain as by-product from the production of hydrogen peroxide, which is enough to meet the demand.

(d) The superiority of the cases in set B over the cases in set A is evident in table 4 where the model opt for the production of chemicals which in set A are found unviable to be produced. Such chemicals to be produced in all cases in set B are cumene, cyclohexane, isophthalic acid, methanol, toluene diamene and caprolactam.

(e) The usage level of 1.19 ton produced/ton demand is obtained in case G which is much lower than cases E and F for chlorobenzene. This behaviour is attributed to the selection of chlorobenzene's route for the production of phenol in cases E and F, and the selection of sulphonation of benzene in case G. This type of drastic change in usage level is a noticeable occurrence for different priority structure with the same goal target. This is due to the shift to an alternative technology that the model finds attractive to produce a chemical in order to satisfy the given priority structure.

(f) The selection of dehydrochlorination of methyl chloroform's process to produce vinylidene chloride in case G provides enough trichloroethylene as by-product to meet the specified demand.

(g) For Polypropylene, each of the three cases takes different processes for its production. In cases E, F and G, the vapour process (BASF technology), slurry process and new slurry process are taken respectively.

(h) In the three cases, G_3 is overachieved by $\$5.04 \times 10^7$ which is the global minimum of the imported cost goal for the given set of the demand. In case E G_4 is underachieved by 5.50×10^5 metric tonnes, in case F G_2 is overachieved by $\$7.94 \times 10^5$ while there is no underachievement or overachievement of G_2 and G_4 in case G. This indicates that the priority structure used in case G satisfies the petrochemical requirement of the country by meeting the local cost goal and feedstock consumption goal.

5. MAXIMA AND MINIMA OF GOAL TARGETS UNDER DIFFERENT PRIORITY STRUCTURES

The maxima and minima of goal targets under different priority structures for both projected demand and when the demand is doubled are shown in table 5. For the set B, in each case the minimum imported cost goal is the global minimum which is $\$5.04 \times 10^7$. It is noted from table 5 that with respect to the given priority structure, the maximum of each goal doubled when the demand is doubled but the minimum does not double with doubled demand. It is then deduced that maximum goal target is a function of cost coefficient and demand while the minimum goal target is a function of cost coefficient, demand level and priority factor attached to the multidimensional objective function of G.P. model.

6. EXPORT POTENTIALS

After satisfying the local demand, efforts should be geared towards meeting the petrochemicals' demand of other countries. Most African countries have little or no petroleum reserves, coal and natural gas which are the necessary inputs to petrochemical industry. Although embarking on exportation of petrochemical is fraught with dangers like international politics and cut-throat competition among nations, we still find it appropriate to apply G.P. model to see the effect on process selections, usage levels and deviations from the set goals when the demand levels are doubled for all the petrochemicals subject to priority structures $P_1 = P_2 = 10^9$, $P_4 = 10^5$, $P_3 = 1.0$ (case B in set A) and $P_1 = P_2 = P_3 = 10^9$, $P_4 = 10^5$ (case G is set B).

In order to implement this decision, the maxima of the local cost goal and feedstock consumption goal to meet the doubled demand as determined. The local cost goal and the feedstock consumption goal are set at their maxima while the imported cost goal is set at zero. Parts of the results for case B and case G are shown in table three under column D and table 4 under column H respectively. Shown in table 6 for set B are some of the processes that their usage levels do not double for doubled demand, and the reasons for such behaviour.

COMMENT ON CASE G IN SET B

(a) A bigger plant is needed to produce acetic acid when the demand is doubled due to the reduction of acetic acid's by-product obtained from terephthalic acid (crude) via acetaldehyde.

(b) Since in set B, we ensure that the global minimum is not exceeded, it is not suprising that the same number of chemicals are recommended for production when the demand is doubled. We obvserve that there are changes in technology routes for the manufacture of a few chemicals when the demand is doubled. For example, for the production of acrylonitrile, the process is shifted when the demand is doubled from ammoxidation of propylene to cyanation/oxidation of ethylene, and in cyclohexanol's production, a shift in the technology rute from oxidation of cyclohexane to reaction of boric acid and cyclohexane is noted.

(c) The entire shift in technology to dehydrochlorination of 1,1,2 trichloroethane for the production of vinylidene chloride when the demand is doubled necessitates the production of trichloroethylene via chlorination of ethylene dichloride.

7. CONCLUDING REMARKS

The global minimum of imported cost goal for a given demand under any priority structure is find to be equal to the minimum obtained when equal priority of 1.0 is assigned to all goals.

For the same goal target under different priority structures, most of the selected technologies are identical except for a few chemicals, it is preferable either to shift to another process or to simply import the chemicals.

The tested cases in set B are found to be superior to the tested cases in set A under different priority structures in the G.P. model. In set B, the model opts for the production of chemicals which in set A are found unviable to be produced.

NOMENCLATURE

a_{ij}/b_{ik} the amount of unfabricated/fabricated material i per unit of chemical transformafation j/fabrication technology k. Postive if produced, negative if

consumed, zero if neither produced nor consumed.

X_j the level of operation of process j.

Y_k the level of operation of process k.

I_i the amount of imported material i

C_j the units operating cost for chemical transformation j.

C_k the unit operating cost for fabrication technology k.

P_i the local unit price for material i.

B_i the imported units price for material i.

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Table 1 : The selected petrochemicals that constitute the model industry and their functions, that is, whether primary input 1, intermediate M end/or and - product 0.

CHEMICAL	FUNCTION
1. Acetaldehyde	MO
2. Acetic acid	MO
3. Aceptic anhydride	MO
4. Acetone	MO
5. Acetylene	I
6. Acrolein	MO
7. Acrylamide	MO
8. Acrylic acid	MO
9. Acrylonitrile	MO
10 Adipic acid	MO
11. Adiponitrile	MO
12. Allyl alcohol	MO
13. Allyl chloride	MO
14. Amonia	I
15. Ammonium sulphate	O
16. Aniline	MO
17. Benzene	IMO
18. Bisphenol-A	MO
19. Butadiene	MO
20. 1,4-Butanediol	MO
21. n-Butanol	MO
22. s-Butanol	MO
23. n-Butylene	I
24. n-Butyraldehyde	MO
25. Calcium oxide	I
26. Caprolactam	MO
27. Carbon dioxide	I
28. Carbon monoxide	I
29. Chlorine	MO
30. Chlorobenzene	MO
31. Chloroprene	MO
32. Cumene	MO
33. Cyclochexane	MO
34. Cyclohexanol	MO
35. Cyclohexanone	MO
36. Diethylene glycol	MO
37. Dimethyl terephthalate	MO
38. Dinitrotoluene	MO
39. Dioctyl phthalate	MO
40. Dodecene	I
41. Dodecyl benzene	I
42. Dipropylene glycol	MO
43. Epichlorohydrin	MO
44. Ethanol	MO
45. Ethyl acetate	MO
46. Ethyl acrylate	MO
47. Ethyl benzene	MO
48. Ethylene	I
49. Ethylene dichloride	MO
50. Ethylene glycol	MO
51. Ethylene oxide	MO
52. 2-Ethyl hexanol	MO
53. Formaldehyde	MO
54. Glycerine	MO
55. Heptenes	I
56. Hexamethylene diamine	MO
57. Hydrogen	I
58. Hydrogen chloride	I
59. Hydrogen cyanide	I
60. Hydrogen peroxide	MO
61. Isobutylene	I
62. Isooctanol	MO
63. Isophthalic acid	MO
64. Isoprene	MO
65. Isopropanol	MO
66. Maleic anhydride	MO
67. Melamine	MO
68. Methanol	MO
69. Methyl acrylate	MO
70. Methylene diphenylene diisocyanate (MDI)	MO
71. Methyl ethyl ketone (MEK)	MO
72. Methyl Isobutyl Ketone (MIBK)	MO
73. Methyl methacrylate	MO
74. Naphthalene	I
75. Nitric acid	MO
76. Nitrobenzene	MO
77. Oleum	I
78. Oxygen	I
79. Phenol	MO
80. Phosgene	MO
81. Phthalic anhydride	MO
82. Propylene	I
83. Propylene glycol	MO
84. Propylene oxide	MO
85. Sodium carbonate	I
86. Sodium chloride	I
87. Sodium hydroxide	MO
88. Styrene	MO
89. Sulphur	I
90. Sulphuric acid	MO
91. Terephthalic acid (fiber)	MO
92. Terephthalic acid (crude)	MO
93. Toluene	I
94. Toluene Diamine	MO
95. Toluene diisocyanate	MO
96. Trichloroethylene	MO
97. Triethylene glycol	MO
98. Urea	MO
99. Vinyl acetate	MO
100 Vinyl chloride	MO
101. Vinylidene chloride	MO
102. m-Xylene	I
103. o-Xylene	I
104. p-Xylene	I
105. Acetal resin	O
106. Acrylic fibers	O
107. Acrylonitrile-Butadiene-Styrene(ABS)	O
108. Butyl rubber	O
109. Epoxy resin	O
110. Melamine-Formaldehyde (molding)	O
111. Melamine-Formaldehyde (syrup)	O
112. Modacrylic fibers	O
113. Nitrile barrier (barex)	O
114. Nitrile barrier (cylopac)	O
115. Nitrile barrier (lopac)	O
116. Nitrile rubber	O
117. Nitrile rubber (latex)	O
118. Nylon 6 (chips)	O
119. Nylon 6 (melts)	O
120. Nylon 66 (chips)	O
121. Phenol-formaldehyde (molding)	O
122. Phenol-formaldehyde (syrup)	O
123. Polyacrylamide	O
124. Polyacrylate (latex)	O
125. Polyacrylate (pellets)	O
126. Polybutadiene	MO
127. Polybutylene terephthalate(glass-filled)	O
128. Polybutylene terephthalate (plain)	O
129. Polychloroprene	O
130. Polyether polyol (glycerine)	MO
131. Polyether polyol (sorbitol)	O
132. Polyether polyl (phosphate)	O
133. Polyethylene (high density)	O
134. Ployethylene (low density)	O
135. Polyethylene glycol	O
136. Polyethylene terephthalate	O
137. Polyisoprene	O
138. Polyisoprene (latex)	O
139. Polymethyl methacrylate	O
140. Polypropylene	O
141. Polypropylene glycol	O
142. Polystyrene (crystal grade)	O
143. Polystyrene (impact grade)	O
144. Ploystyrene (expandable beads)	O
145. Polyurethane (flexible)	O
146. Polyurethane (rigid foam)	O
147. Polyvinyl acetate	O
148. Polyvinyl acetate (latex)	O
149. Polyvinyl alcohol	O
150. Ploywinyl butyral	O
151. Polyvinyl chloride (general)	O
152. Polyvinyl chloride (latex)	O
153. Styrene Acrylonitrile	O
154. Styrene-Butadiene rubber (SBR)	O
155. S B R. (latex)	O
156. Unsaturated polyester (U P) (general)	O
157. U P (Corrosion resistant)	O
158. U P (fire retardant)	O
159. Urea-Formaldehyde (molding)	O
160. Urea-Formaldehyde (syrup)	O
161. Vinyl acetate/Ethylene (latex)	O
162. Vinyl chloride/Vinyl acetate	O
163. Vinylidene chloride/Vinyl chroride	O
164. Vinylidene chloride/Ethyl acrylate/methyl methacrylate	O

Table 2: List of Technology used to manufacture the set of petrochemicals in the model and their process numbers, PN.

SN	PN	TECHNOLOGY
1.	1	ACETALDEHYDE via one step oxidation of ethylene.
2.	2	ACETALDEHYDE via two step oxidation of ethylene.
3.	3	ACETALDEHYDE via oxidation of ethanol.
4.	1	ACETIC ACID via carbonylation of methanol.
5.	2	ACETIC ACID via air oxidation of acetaldehyde.
6.	3	ACETIC ACID via oxidation of n-butylenes.
7.	1	ACETIC ANHYDRIDE via oxidation of acetaldehyde.
8.	2	ACETIC ANHYDRIDE via ketene and acetic acid.
9.	1	ACETONE via dehydrogenation of isopropanol.
10.	2	ACETONE via oxidation of propylene.
11.	1	ACROLEIN via oxidation of propylene.
12.	1	ACRYLAMIDE via hydration of acrylonitrile (fixed bed catalyst).
13.	2	ACRYLAMIDE via hydration of acrylonitrile (suspended catalyst).
14.	3	ACRYLAMIDE via sulphuric acid process.
15.	1	ACRYLIC ACID via oxidation of propylene (two step vapour phase).
16.	2	ACRYLIC ACID via carbonylation of acetylene.
17.	1	ACRYLONITRILE via amoxidation of propylene.
18.	2	ACRYLONITRILE via cyanation/oxidation of ethylene.
19.	1	ADIPIC ACID via air oxidation of cyclohexane.
20.	2	ADIPIC ACID via oxidation of cyclohexanol with nitric acid.
21.	1	ADIPONITRILE via adipic acid and ammonia.
22.	2	ADIPONITRILE via hydrodimerization of acrylonitrile.
23.	1	ALLYL ALCOHOL vis isomerization of propylene oxide.
24.	2	ALLYL ALCOHOL via acrolein and s-butanol.
25.	1	ALLYL CHLORIDE via chlorination of propylene.
26.	1	ANILINE via hydrogenation of nitrobenezene.
27.	2	ANILINE via ammolysis of cyclohexanol.
28.	3	ANILINE via phenol and ammonia.
29.	1	BENZENE via hydroalkylation of toluene.
30.	2	BENZENE via disproportionation of toluene.
31.	1	BISPHENOL-A via phenol and acetone.
32.	1	BUTADIENE via dehydrogenation of n-butylenes.
33.	2	BUTADIENE via oxidative dehydrogenation of n-butylenes.
34.	1	1,4-BUTANEDIOL via acetylene and formaldehyde.
35.	2	1,4-BUTANEDIOL via butadiene and acetic acid.
36.	3	1,4-BUTANEDIOL via propylene and acetic acid.
37.	4	1,4-BUTANEDIOL via propylene oxide.
38.	1	N-BUTANOL via propylene (conventional oxo).
39.	2	N-BUTANOL via propylene (cobalt-phosphine catalyst).
40.	3	N-BUTANOL via propylene (rhodium catalyst).
41.	1	S-BUTANOL via sulphonation of n-butylene.
42.	1	N-BUTYRALDEHYDE via oxonation of proplene.
43.	1	CAPROLACTAM via hexahydrobenzoi acid.
44.	2	CAPROLACTAM via nitration of cyclohexane.
45.	3	CAPROLACTAM via phenol process.
46.	4	CAPROLACTAM via photonitration of cyclohexane.
47.	5	CAPROLACTAM via cyclohexanone and hydroxylamine.
48.	1	CHLORINE via electrolysis of chloride in diaphragm cells
49.	1	CHLOROBENZENE via chlorination of benzene
50.	2	CHLOROBENZENE via oxychlorination of benzene.
51.	1	CHLOROPRENE via chlorination of butadiene.
52.	2	CHLOROPRENE via dimerization of acetylene.
53.	1	CUMENE via benzene and propylene.
54.	1	CYCLOHEXANE via hydrogenation of benzene.
55.	1	CYCLOHEXANOL via oxidation of cyclohexane.
56.	2	CYCLOHEXANOL from cyclohexane (boric acid).
57.	3	CYCLOHEXANOL via oxidation of cyclohexane.
58.	1	CYCLOHEXANONE via dehydrogenation of cyclohexanol.
59.	2	CYCLOHEXANONE via oxidation/ dehydrogenation of cyclohexane.
60.	1	DIMETHYL TEREPHTHALATE via methanol and p-xylene.
61.	2	DIMETHYL TEREPHTHALATE via esterification of terephthalic acid.
62.	1	DINITROTOLUENE via nitration of toluene.
63.	1	DIOCTYL PHTHALATE via 2-ethylhexanol and phthalic anhydride.
64.	1	DODECYL BENEZENE via dodecene and benzene.
65.	1	EPICHLOROHYDRIN via chlorination of allyl chloride.
66.	1	ETHANOL via hydration of ethylene.
67.	1	ETHYL ACETATE via esterification of acetic acid with ethanol.
68.	2	ETHYL ACETATE via dimerization of acetaldehyde.
69.	1	ETHYL ACRYLATE via esterification of acrylic acid with ethanol.
70.	2	ETHYL ACRYLATE via acrylonitrile.
71.	3	ETHYL ACRYLATE via carbonylation of acetylene.
72.	1	ETHYLBENZENE via benzene and ethylene.
73.	1	ETHYLENE DICHLORIDE via chlorination of ethylene.
74.	2	ETHYLENE DICHLORIDE via oxychlorination of ethylene.
75.	1	ETHYLENE GLYCOL via hydration of ethylene oxide.
76.	2	ETHYLENE GLYCOL via oxidation of ethylene.
77.	1	ETHYLENE OXIDE via oxidation of ethylene.
78.	2	ETHYLENE OXIDE via chlorohydration of ethylene.
79.	2	2-ETHYLHEXANOL via oxo process.
80.	1	FORMALDEHYDE via oxidation of methanol.
81.	1	GLYCERINE via hydrolysis of epichlorohydrin.

SN	PN	TECHNOLOGY
82.	2	GLYCERINE via allyl alcohol and hydrogen peroxide.
83.	1	HEXAMETHYLENE DIAMINE via acrylonitrile.
84.	2	HEXAMETHYLENE DIAMINE via adipic acid and ammonia.
85.	3	HEXAMETHYLENE DIAMINE via hydrocyanation of butadiene.
86.	1	HYDROGEN PEROXIDE via oxidation of isopropanol.
87.	1	ISOOCTANOL via heptenes (one step oxonation).
88.	2	ISOOCTANOL via heptenes (two step oxonation).
89.	1	ISOPHTHALIC ACID via oxidation of m-xylene.
90.	1	ISOPRENE via dimerization of propylene.
91.	2	ISOPRENE via formaldehyde and isobutylene.
92.	1	ISOPROPANOLvia hydration of propylene.
93.	2	ISOPROPANOL via propylene (cation exchange).
94.	1	MALEIC ANHYDRIDE via oxidation of benzene.
95.	1	MELAMINE via BASF process.
96.	2	MELAMINE via CHEMIE process.
97.	3	MELAMINE via NISAN process.
98.	4	MELAMINE via STAMICARBON process.
99.	1	METHANOL via hydrogenation of carbon monoxide (high pressure).
100.	2	METHANOL via hydrogenation of carbon monoxide (low pressure).
101.	1	METHYL ACRYLATE via esterification of acrylic acid.
102.	1	METHYLENE DIPHENYLENE DIISOCYANATE (MDI) via aniline and formaldehyde.
103.	1	METHL ETHYL KETONE via dehydrogenation of s-butanol.
104.	2	METHYL ETHYL KETONE via oxidation of n-butylene.
105.	1	METHYL ISOBUTYL KETONE via direct condensation of acetone.
106.	1	METHYL METHACRYLATE via cyanohydration of acetone.
107.	2	METHYL Methacrylate via methanol and iso-butylene.
108.	1	NITRIC ACID via oxidation of ammonia (UHDE type process).
109.	1	NITROBENZENE via nitration of benzene.
110.	1	PHENOL via oxidation of cumene.
111.	2	PHENOL via dehydrochlorination of chlorobenzene.
112.	3	PHENOL via alkaline hydrolysis of chlorobenzene.
113.	4	PHENOL via sulphonation of benzene.
114.	1	PHOSGENE via chlorine and carbon monoxide.
115.	1	PHITHALIC ANHYDRIDE via oxidation of o-xylene.
116.	2	PHTHALIC ANHYDRIDE via oxidation of naphthalene.
117.	1	PROPYLENE GLYCOL via hydration of propylene oxide.
118.	1	PROPYLENE OXIDE via chlorohydration of propylene.
119.	2	PROPYLENE OXIDE via oxidation of propylene with t-butyl hydroperoxide.

SN	PN	TECHNOLOGY
120.	1	STYRENE via degydrogenation of ethylbenzene.
121.	2	STYRENE via ethylbenzene by hydroperoxide process.
122.	1	SULPHURIC ACID via double absorption process.
123.	1	TEREPHITHALIC ACID (FIBER GRADE) via p-xylene.
124.	2	TEREPHITHALIC ACID (FIBER GRADE) via crude TPA.
125.	3	TEREPHTHALIC ACID (CRUDE GRADE) via oxidation of p-xylene.
126.	4	TEREPHTHALIC ACID (CRUDE GRADE) via acetaldehyde.
127.	1	TOLUENE DIAMINE via hydrogenation of dinitrobenzene.
128.	1	TOLUENE DIISOCYANATE via phosgenation of toluene diamine.
129.	1	TRICHLOROETHYLENE via chlorination of ethylene dichloride.
130.	1	UREA via amonia and carbon dioxide.
131.	1	VINYL ACETATE via athylene and acetic acid.
132.	2	VINYL ACETATE via acetylene and acetic acid.
133.	1	VINYL CHLORIDE via chlorination and oxychlorination of ethylene.
134.	2	VINYL CHLORIDE via dehydrochlorination of ethylene dichloride.
135.	3	VINYL CHLORIDE via hydrochlorination of acetylene.
136.	1	VINYLIDENE CHLORIDE via dehydrochlorination of 1,1,2 trichloroethane.
137.	2	VINYLIDENE CHLORIDE via dehydrochlorination of methyl chlorofor.
138.	1	ACETAL RESIN from trioxane and ethylene oxide.
139.	2	ACETAL RESIN from formaldehyde.
140.	1	ACRYLIC FIBERS (POLYMER) from acrylonitrile and methyl methacrylate (continuous solution polymerization).
141.	2	ACRYLIC FIBERS (POLYMER) from acrylonitrile and methyl acrylate (continous solution polymerization).
142.	3	ACRYLIC FIBERS (POLYMER) from acrylonitrile and methyl acrylate (continous suspention polmzn).
143.	4	ACRYLIC FIBERS (POLIMER) from acrylonitrile and vinyl acetate (batch suspension polymerization).
144.	1	ACRYLONITRILE-BUTADIENE-STYRENE (ABS) graft resin by emulsion/emulsion polymerization.
145.	2	ABS graft resin by suspension/emulsion polymerization.
146.	3	ABS graft resin by bulk/suspension polymerization.
147.	1	BUTYL RUBBER from isobutylene.
148.	1	EPOXY RESIN from low molecular weight DGEBA resin (batch proc.).
149.	2	EPOXY RESIN from low molecular weight DGEBA resin (continous process).
150.	3	EPOXY RESIN from solid DGEBA resin (batch process).
151.	1	MELAMINE-FORMALDEHYDE (molding compound).
152.	2	MELAMINE-FORMALDEHYDE RESIN (syrup).

SN PN	TECHNOLOGY
153.1	MODACRYLIC FIBER (POLYMER) from acrylonitrile and vinyl chloride (contnous suspension polymerization).
154.2	MODACRYLIC FIBER (POLYMER) from acrylonitrile and vinyl acetate (batch suspension polymerization.
155.1	NITRILE BARRIER RESIN (BAREX) by emulsion polymerization.
156.2	NITRILE BARRIER RESIN (CYLOPAC) by emulsion polymerization.
157 3	NITRILE BARRIER RESIN (LOPAC) by SUSPENSION polymerization.
158.1	NITRILE RUBBER by cold emulsion polymerization.
159.2	NITRILE RUBBER (LATEX) by hot emulsion polymerization.
160.1	NYLON 6 (CHIPS) from caprolactam.
161.2	NYLON 6 (MELT) from caprolactam.
162.3	NYLON 66 (CHIPS) from adipic acid and hexamethylene diamine.
163.1	PHYNOL-FORMALDEHYDE (Novolac molding process).
164.2	PHYNOL-FORMALDEHYDE (SYRUB) (batch process).
165.1	POLYACRYLAMIDE (ANIONIC) by polymerization & hydrolysis.
166.1	POLYACRYLATE (47% LATEX) by batch emulsion polymerization.
167.2	POLYCRYLATE (PELLET) by batch suspension polymerization.
168.1	POLYBUTADIENE by cobalt-catalyzed polymerization.
169.2	POLYBUTADIENE by lithium catalyzed polymerization.
170.3	POLYBUTADIENE by iodined-ziegler catalyzed polymerization.
171.4	POLYBUTADIENE by nickel catalized polymerization.
172.1	POLYBUTYLENE TEREPHTHALATE (PBT) RESIN (glass filled).
173.2	PBT RESIN (plain).
174.1	POLYCHLOROPRENE (NEOPRENE) via butadiene.
175.1	POLYETHER POLYOL (Sorbitol-based hexol) from propylene oxide and sorbitol.
176.2	POLYETHER POLYOL (Phosphorus contaning) from propylene oxide and phosphoric acid.
177.3	POLYETHER POLYOL (Glycerine based triol) from propylene oxide and glycerine.
178.1	POLYETHYLENE (HD) via philips technology.
179.2	POLYETHYLENE (HD) via solvay tech. [ziegler catalyst].
180.3	POLYETHYLENE (HD) via union carbide tech. (gas phase process).
181.4	POLYETHYLENE (HD) via hoeshst technology.
182.5	POLYETHYLENE (HD) via montedison technology.
183.6	POLYETHYLENE (HD) via stamicarbon technology.
184.1	POLYETHYLENE (LD) from autoclave reactor (compartmented).
185.2	POLYETHYLENE (LD) from autoclave reactor (back-mixed).
186.3	POLYETHYLENE (LD) from a tubular reactor.
187.1	POLYETHYLENE GLYCOL from ethylene oxide and diethylene glycol.
188.1	POLYETHYLENE TEREPHTHALATE (PET) from dimethyl terephthalate (DMT) and ethylene glycol.
189.2	POLYETHYLENE TEREPHTHALATE (PET) from TPA and ethylene glycol.
190.1	POLYISOPRENE by a ziegler catalyst.
191.2	POLYISOPRENE by a lithium catalyst.
192.3	POLYISOPRENE (Latex) from polyisopene.
193.1	POLYMETHYL-METHACRYLATE (Sheet) by continues casting.
194.2	POLYMETHYL-METHACRYLATE (Sheet) by batch casting.
195.1	POLYPROPYLENE by liquid phase bulk process (dart technology).
196.2	POLYPROPYLENE by vapour phase process (BASF technology).
197.3	POLYPROPYLENE by slurry process.
198.4	POLYPROPYLENE by solution process.
199.5	POLYPROPYLENE by new slurry process.
200.1	POLYPROPYLENE GLYCOL from propylene oxide and propylene glycol.
201.1	POLYSTYRENE (Crystal grade) by bulk polymerization.
202.2	POLYSTYRENE (Impact grade) by suspension polymerization.
203.3	POLYSTYRENE (Impact grade) by bulk/susp. polymerization.
204.4	POLYSTYRENE (Expandable beads) by susp. polymerization.
205.1	POLYURETHANE (Rigid foam slab stock) from polyether polyol and toluene diisocyanate.
206.2	POLYURETHANE (Flexible foam sheet, fire retardant) from polyether polyol and methylene diphenylene di-isocyanate (MDI).
207.1	POLYVINYL ACETATE by solution polymerization.
208.2	POLYVINYL ACETATE by suspension polymerization.
209.3	POLYVINYL ACETATE (62% Solid latex) by emulsion polymerization.
210.4	VINYL ACETATE/ETHYLENE COPOLYMER latex (60% solid) by emulsion polymerization.
211.1	POLYVINYL ALCOHOL from vinyl acetate.
212.1	POLYVINYL BUTYRALDEHYDE by condensation of polyvinyl alcohol with butyradehyde.
213.1	POLYVINYL CHLORIDE (PVC) (General purpose) by liquid phase bulk polymerization.
214.2	PVC (General purpose) by suspension polymerization.
215.3	PVC (Latex) by emulsion process (continous polymerization).
216.4	PVC (Latex) by emulsion process (batch polymerization).
217.5	VINYL CHLORIDE?VINYL ACETATE COPOLYMER by suspension polymerization.
218.1	STYRENE-ACRYLONITRILE (SAN) by bulk polymerization.
219.2	SAN by continous emulsion polymerization.
220.3	SAN by batch emulsion polymerization.
221.4	SAN by suspension polymerization.
222.1	STYRENE-BUTADIENE RUBBER (SBR) by cold emulsion polymerization.
223.2	SBR by solution polymerization.
224.3	SBR (Latex) by hot emulsion polymerization.
225.1	UNSATURATED POLYESTER RESIN (UP) (General purpose) from propylene glycol and anhydrides (batch fusion process).

SN	PN	TECHNOLOGY
	226.2	UP (General purpose) from propylene glycol and anhydrides (batch solvent process).
	227.3	UP (General purpose) from propylene oxide and anhydrides (batch process).
	228.4	UP (General purpose) from propylene oxide and anhydrides) by a continus process).
	229.5	UP (General purpose) by a continuous glycol process.
	230.6	UP (Corosion resistant) via Isophthalic acid based reaction (fusion process).
	231.7	UP (Fire resistant) by fusion process.
	232.1	UREA-FORMALDEHYDE (Molding compound).
	233.2	UREA-FORMALDEHYDE (Syrup).
	234.1	VINYLIDENE CHLORIDE VINYL CHLORIDE RESIN by suspension polymerization.
	235.2	VINYLIDENE CHLORIDE/ETHYL ACRYLATE/METHL METHACRYLATE Latex by emulation Polymerization.

Table3: Process selections and usage levels for cases A,B,C and D when G_2 and G_4 are at their maxima and G_3=0, in set A

CHEMICAL	PN	USAGE LEVEL A	B	C	D
Acetaldehyde	3	5.10	4.95	4.11	5.04
Acetic acid	2			2.61	
Acetic anhydride	2	1.03	1.03	1.00	1.03
Acetone	1			1.23	
Acrolein	1	3.50	4.88	1.24	3.50
Allyl alcohol	1			.90	
	2	1.00	1.55	.10	1.00
Allyl chloride	1	9.95	6.22	9.95	9.95
Butadiene	1	5.99	5.99	5.66	5.90
1,4-Butanediol	2	2.79	2.79		2.79
	4			1.00	
Chlorobeneze	1	18.47			18.47
	2		1.19	1.19	
Chloroprene	1	1.00	1.00		1.00
	2			1.00	
Ethanol	1	37.71		31.28	6.12
Ethylene dichloride	1	1.92			
	2	1.24	.87	3.17	.39
Glycerine	1	4.43		4.43	4.43
	2		4.43		
Hydrogen peroxide	1	.49	.22		.22
Isophthalic acid	1	1.21		1.21	1.21
Methyl Isobutyl Ketone	1	1.27	1.27	1.00	
1.27					
Phenol	2	2.96			2.96
	4		2.96	2.97	
Phosgene	1	4.49	4.49	4.49	
4.49					
Propylene glycol	1	1.20	1.20	1.20	1.20
Styrene	1			5.84	
	2	5.84			5.88
Terephthalic acid (crude)	3	357.37	574.61		357.37
	4	3080.0	2967.70	1.0	3018.20
Urea	1	.64	1.11	1.11	
Polycloroprine (low dens.)	1	1.00	1.00	1.00	1.00
Polyethylene (high den.)	2				1.00
	6	1.00		1.00	
Polyethylene (low dens.)	1	1.00	1.00	1.00	1.00
Polyethylene terephthalat	1		1.00		1.00
	2	1.00		1.00	
Polymethy-l methacrylate	2	1.00	1.00	1.00	1.00
Polypropylene	2				1.00
	4	1.00	1.00	.34	
	5			.66	
Polystyrene (expandable)	4	1.00	1.00	1.00	1.00
Polyurethane (rigid foam)	2	1.00	1.00	1.00	1.00
Polyvinyl acetate	2	1.00	1.00	1.00	1.00
Polyvinyl chloride (gen.)	1			1.00	
	2	1.00	1.00		1.00
SBR	2	1.01	1.01	1.01	1.01

Table 4: Process selections and usage levels for cases E,F,G. and H when G_2 and G_4 are at their maxima and G_3=0, in set B

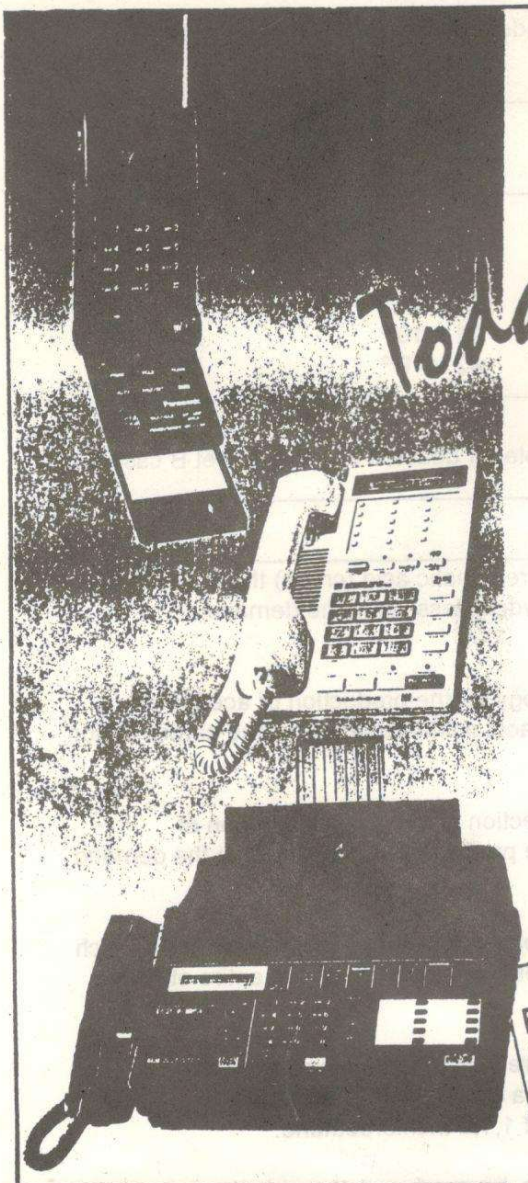
CHEMICAL	PN	USAGE LEVEL E	F	G	H
Acetaldehyde	1	2.71		4.45	3.70
	3		2.78		
Acetic acid	1	1.39			.71
	3		.37	.27	
Acrolein	1	3.50	3.50	3.50	3.50
Caproclactam	4	1.00	1.00	1.00	1.00
Chlorobenzene	2	12.24	20.33	1.19	12.53
Cumene	1	1.00	1.00	1.00	1.00
Cyclohexane	1	2.83	2.90	3.08	2.83
Ethyl acetate	2	3.59	3.59	3.59	3.59
Ethylene oxide	1	1.02	1.03	1.02	1.02
Hydrogen peroxide	1	1.00	1.00	1.00	1.00
Isophthalic acid	1	1.21	1.21	1.21	1.21
Isopropanol	1	5.99		5.99	5.99
	2		5.99		
Methanol	1	4.28	3.57	3.66	4.03
Phenol	2	1.89			1.94
	3		2.98		
	4	.18		2.07	.13
Toluene Diamine	1	47.65	47.65	47.65	47.65
Toluene diisocyanate	1	4.70	4.70	4.70	4.70
Trichloroethylene	1	1.00	1.00		1.00
Urea	1	1.11	1.11	1.11	1.11
Vinyl acetate	1	3.24	3.24	3.24	3.24
Vinyl chloride	2		2.03		
	3	2.03		2.05	2.03
Vinylidene Chloride	1	2.20	2.20	1.18	2.20
	2			1.03	
ABS	1		1.00		
	3	1.00		1.00	1.00
Nylon 66 (chips)	3	1.00	1.00	1.00	1.00
Polychloroprene	1	1.00	1.00	1.00	1.00
Polyethylene (high den.)	1	1.00			
	2		1.00		
	6			1.00	1.00
Polyethylene (low dens.)	1		1.00		
	2	1.00		1.00	1.00
Polyethylene glycol	1	1.00	1.00	1.00	1.00
Polyethylene terephthalat	1		1.00		.52
	2	1.00		1.00	.48
Polypropylene	2	1.00			1.00
	5			1.00	
Polypropylene glycol	1	1.00	1.00	1.00	1.00
Polystyrene (crystal)	1	1.02	1.02	1.02	1.02
Polyvinyl acetate	2	1.00	1.00	1.00	1.00
Polyvinyl chloride (gen.)	1	1.00			
	2		1.00	1.00	1.00
Styrene-Acrylonitrile	3		1.00	1.00	1.00

Table 5: Maxima and minima of goal targets under different priority structures.

Priority	Minimum		Maximum	
	G_3	G_4	G_3	G_4
Equal	$.50 \times 10^8$	$.59 \times 10^6$	$.21 \times 10^{10}$	$.27 \times 10^7$
Case A	$.27 \times 10^9$	0.0	$.21 \times 10^{10}$	$.27 \times 10^7$
Case B	$.70 \times 10^9$	0.0	$.21 \times 10^{10}$	$.27 \times 10^7$
Case C	$.76 \times 10^7$	0.0	$.21 \times 10^{10}$	$.27 \times 10^7$
Case D	$.98 \times 10^9$	0.0	$.42 \times 10^{10}$	$.55 \times 10^7$

Table 6 : Processes that their usage levels do not double for doubled demand in Set B case G

Chemicals	PN	Dev.	Reasons
Acetaldehyde	1	-.75	The usage level of terephthalic acid (crude) through reaction of acetadehyde is less when the demand is doubled
Acetic acid	1	.70	A shift in the technology for the production of acetic acid from air oxidation of acetaldehyde's route to the carbonylation of methanol's route.
Chlorobenzene	2	11.34	This is due to the selection of dehydrochlorination of chlorobenzene for the production of phenol when the demand is doubled.
Ethylene dichloride	2	.32	This is due to the selection of a single technology route which is oxychlorination of ethylene to produce the entire ethylene dichloride.
Vinylidene chloride	1	1.02	This is due to the entire shift of technology to produce vinylidene chloride to a single process which is dehydrochlorination of 1,1,2 trichloroethane.
polyethylene terephthalate	2	-.52	PET is now viable to be produced through the two available technologies when the demand is doubled. 48% of the demand is satified through the reaction TPA and Ethylene glycol's route.



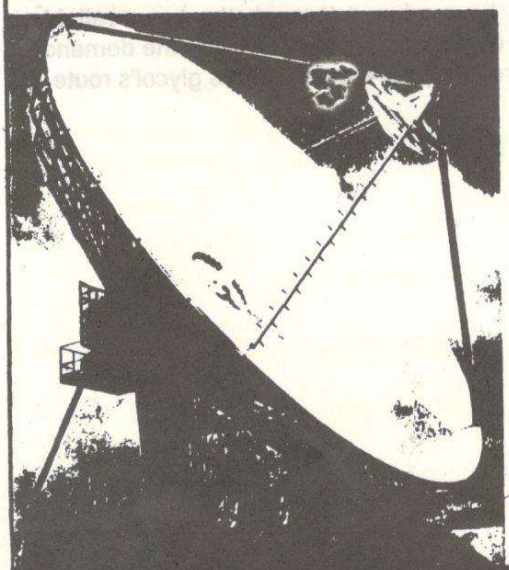
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