



**HAL**  
open science

## Extending Group Technology to the identification and the analysis of enterprises networks

Dario Antonelli, Agostino P.M. Villa, Irene Cassarino

► **To cite this version:**

Dario Antonelli, Agostino P.M. Villa, Irene Cassarino. Extending Group Technology to the identification and the analysis of enterprises networks. *International Journal of Production Research*, 2007, 45 (17), pp.3881-3892. 10.1080/00207540600844035 . hal-00512929

**HAL Id: hal-00512929**

**<https://hal.science/hal-00512929>**

Submitted on 1 Sep 2010

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



**Extending Group Technology to the identification and the analysis of enterprises networks**

Journal:	<i>International Journal of Production Research</i>
Manuscript ID:	TPRS-2006-IJPR-0063
Manuscript Type:	Original Manuscript
Date Submitted by the Author:	25-Jan-2006
Complete List of Authors:	Antonelli, Dario Villa, Agostino; ed Economia della Azienda, Dipartimento di Sistemi di Produzione Cassarino, Irene; Dipartimento dei Sistemi di Produzione ed Economia dell'Azienda
Keywords:	NETWORKS, PERFORMANCE ANALYSIS, ENTERPRISE MODELLING
Keywords (user):	



A. Villa et al.

*International Journal of Production Research*, Vol. X, No. X, Month 2006, xxx–xxx

# Extending Group Technology to the identification and the analysis of enterprises networks

A. VILLA, I. CASSARINO AND D. ANTONELLI\*

Department of Production Systems and Business Economics , Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy

\*Corresponding author. Email: dario.antonelli@polito.it

The paper proposes a practical tool for the identification and analysis of industrial networks among a set of enterprises already linked by trade relationships. The methodology extends the Group Technology (GT) and the Production Flow Analysis (PFA) approach, widely applied in organizing the production inside industrial plants. The main advantage of this approach is the small set of data needed to get a feasible solution. An heuristic procedure, sketched at several degrees of analysis, allows not only the identification of the industrial network, but also, with the contribution of other analytical and theoretical studies, the exploitation of potential or existing organizational structure. If properly supported by other studies covering remaining aspects (social, political) of industrial organization, the tool could be practically useful in recognizing possible improvements in the organization of a given set of enterprises, or also could be used as an investigation instrument for public bodies in exploiting existing or hidden potential industrial networks.

*Keywords:* Networks, Performance Analysis, Performance Evaluation, Co-operation, Enterprises Modelling

*AMS Subject Classification:*

## 1. Introduction

Present contribution was elaborated inside the wide (and not yet structured) field of management and analysis of systems of enterprises which are somehow dependent and somehow autonomous from each others. The study field is improperly attributed to the Supply Chain Management. Aiming at avoiding any confusion about the basic terms or concepts, some widely accepted definitions are reported just below.

‘An industry cluster may be defined very generally as a group of business enterprises and non-business organizations for whom membership within the group is an important element of each member firm’s individual competitiveness’ (Bergman, 1999). The enterprises inside a cluster are connected by ‘buyer-supplier relationships, or common technologies, common buyers or distribution channels, or common labour pools’ (Enright, 1996).

An industry network is ‘a group of firms with restricted membership and specific, and often contractual, business objectives likely to result in mutual financial gains. The members of a network choose each other, for a variety of reasons; they agree explicitly to cooperate in some way and to depend on each other to some extent. Networks develop more readily within clusters, particularly where multiple business transactions have created familiarity and built trust’ (Rosenfeld, 1995).

## Extending Group Technology to the identification and the analysis of enterprises networks

A DEMand & Supply NETwork (DESNET) is a socio-territorial entity characterized by the active presence of a 'population of firms' into a bounded geographical area with specific socio-economic-technical features.

The difference between the terms can be more subtle than a different definition: a cluster could be a group of enterprises which have established in the nearby of each other by chance and that do not collaborate through any significant reciprocal relationships. On the contrary, a network assumes a formal, contractual relationship (at least a contract between buyer and supplier) among the enterprises. A DESNET is by constitution a cluster but it has the possibility and the necessity to develop a networked structure.

If the enterprises inside a cluster are not receiving benefits in terms of economic or technologic or logistic services, they are not actually committed to participate to the cluster. It is the very case of enterprises geographically located in a cluster but not belonging to it in terms of productive exchanges. The crucial factor for DESNET success is cooperation, 'because it economizes on transaction costs and fosters flexibility and innovation' (Beccattini, 1990). In this perspective it must be stressed the importance of the role played by non-business organizations, like industry associations, universities and technological parks. Their approach to the cluster is non competitive or, conversely, it is fully cooperative and it acts toward the other actors as a glue making more attractive the cooperation also among business oriented agents. Three main drivers, inducing a group of enterprises to become a cluster, have been identified (Doeringer, 1996): 1) strategic business opportunities derived from specific kinds of inter-firm alliances; 2) traditional regional factor market advantages (labour pools and localized knowledge spillovers); 3) the role of non-business institutions such as universities, colleges, trade unions, and associations. Furthermore, other factors can be added, like just-in-time trends, niche marketing, and civic capacity.

A study on industry clusters implies two orders of problems:

- identify the clusters and inside every cluster the presence of strong cooperation links that justify the constitution of industry networks, if not already present;
- Analyse the mechanisms and the rules involved in the network operations in order to exploit the advantages of present network organization and possibly to suggest new or different type of associations among enterprises.

The identification of the exact cluster borders and of the mechanisms of cluster organization is a sensitive task. Clusters often benefit from public, government funding. The official cluster definitions (say, defined by government's directives) can be in contrast with a classification based on functional relationships. There is also a dichotomy between the cluster analysis driven by political reasons to strengthen or increase the competitive assets of a region and the same analysis driven by a organization or logistic request to improve the internal efficiency of the supply chains managed inside the cluster or simply to investigate if the cluster really exist or if it be limited to geographic proximity.

Several methods were proposed in the literature to identify and bound a cluster (Czamanski, 1979), involving graph theory, triangularization, factor/principal components analysis for sorting industries into groups based on input-output linkage, as well as statistical cluster analysis (Simchi-Levy, 2002). Also optimization methods based on reduction and balancing of transaction costs (Verwaal, 2004; Faratin, 1998) are available, in theory, in order to recognize the better assets for a cluster of firms.

The main shortcoming of these methods is the difficulty to find the data on which to work. The model proposed in this paper and the method on which it relies to find a solution, is based on the main requirement of feasibility. The smaller the set of data needed, and the simpler the tool to find them, the more effective and serviceable is the method. A compelled choice, from this perspective, is a method which consider the network as an input-output system aimed at producing goods or services for the market (Albino, 2002). The input-output analysis is mainly exploited to deal with the socio-economic and sometimes ecological fields (Albino,

A. Villa et al.

2004; Sangwon, 2004) or in controlling the supply chains of perishable goods (Bogataj, 2005). This study utilises the Production Flow Analysis (PFA) input-output perspective, widely tested and applied in designing and organizing manufacturing plants, but still neglected in the field of supply network management.

Section 2 concisely presents the Group Technology (GT) method of analysis in order to introduce the mathematical model customized for the cluster identification described in Section 3. Section 4 is devoted to the heuristic solution and application of the model, exploiting a practical example, while Section 5 analyses the solution obtained trying to recognize different governance structures according to different cluster compositions.

## 2. The GT approach

The aim of the classical GT philosophy is to analyse a production system in order to obtain a more compact production model by highlighting group of machine tools (cells) and set of similar products (families). As a consequence the process analyst can manage a production problem with a reduced set of variables, aggregated per cell and per family. GT has therefore the scope of simplifying the analysis of the productive system. The PFA approach to the GT consists in the grouping of machines and products based on the analysis of the production flows. Fallout of the analysis is the recognition of the most loaded machines, usually the bottlenecks of the productive system.

The extension to the study of industry clusters is immediate: the machines are replaced by enterprises and the single product is replaced by a whole production typology or by a category of services provided by the enterprise. Extending the GT (with the PFA approach) to the analysis of industry clusters allows focusing the investigation, preparatory for the cluster identification, exclusively on the quantities of products exchanged among firms. The principal sources to fetch input-output data are Chambers of Commerce and the district Associations (see, as an example Distretti Industriali Italiani). By the way, the model is static and not dynamic because the objective is the analysis of possible long term grouping of enterprises (clustering) regardless of the daily production scheduling which however could have been used to collect the necessary input-output data.

All the products are processed by means of 'activities' which represent indifferently a production process, a delivering or any kind of added service. The activities are assigned to firms belonging to the network, by means of an auction. Different activities can be assigned to different firms or to the same firm. The auction is obviously ruled by a bidding system which the firms will choose to participate depending on their profitability and respecting the technological restraints and the productive capability restraints. Therefore, generally speaking, a single enterprise should decide to participate to an auction independently on its belonging to the networks and without any preliminary agreement with other network enterprises.

This assessment justifies the common approach to these kinds of problems which is usually derived by the agent theory. The enterprises behave as intelligent agents which are looking for the maximum individual profit. The agents are called to strategically interact because the whole network profitability, in general, does not correspond to maximum profit for each single enterprise (Faratin, 1998). Nevertheless enterprises, especially SMEs, recognize the need of being part of a network and of collaboration with other similar enterprises.

A cluster arises as soon as some enterprises operating in a similar specific field (same productions or same services provided) activate reciprocal interaction, even if simple, in order to improve their complementarities and to find ways of cooperation. While the cluster is built in a spontaneous fashion, once instituted it has the aim of harmonizing the contribution of the different enterprises to enhance the global production of the whole cluster. A model of a cluster should describe the constitutive moment and its first organization. The rule is: 'every enterprise can contribute to the cluster production in the most convenient way (for the enterprise) but the contribution should be chosen among the set of contributes required by the cluster'. In formal terms this

## Extending Group Technology to the identification and the analysis of enterprises networks

statement forces a mathematical model in form of ‘task allocation’. The layout of a network should be organized in order to minimize the production and delivery costs all over the supply chain for every product considered. The objective of next section is to describe in formal terms the organization of a DESNET by taking into account only the inputs and the outputs measured at the extremities of the enterprises considered as black boxes.

### 3. Deriving a formal model for the analysis of industry networks

The formal description of the problem adopts the following notations.

#### 3.1. Indexes

$i$  = 1, ..., I is the activities index.  
 $j$  = 1, ..., J is the product families index.  
 $m$  = 1, ..., M is the firms index.

#### 3.2. Parameters

$c_{ijm}$  = virtual cost associated to the activity  $i$  executed on product  $j$  in the firm  $k$ .  
 $t_{ijm}$  = time to complete the activity  $i$  executed on product  $j$  in the firm  $k$ .  
 $T_m$  = year productive capacity of the firm  $m$ .  
 $D_j$  = year demand for product  $j$ .  
 $x_{ijm}$  = 1, if the activity  $i$  on part  $j$  is executed by the firm  $m$ , otherwise 0. This is the decision variable.

#### 3.3. Definition of the problem

The problem of the identification and the analysis of industry networks inside a DESNET can be expressed as the minimization with respect to  $x_{ijm}$  of the cost functional expressing the execution of all the activities for a product on firms of the network. It can be described as follows:

$$\min \sum_j D_j \sum_m \sum_i c_{ijm} x_{ijm} \quad (1)$$

The problem (1) is subjected to the following constraints:

$$\sum_j D_j \sum_i x_{ijm} t_{ijm} \leq T_m \quad \forall m = 1, \dots, M \quad (2)$$

$$\sum_m x_{ijm} = 1 \quad \forall i, j \quad (3)$$

The constraints are: (2) the production allocated to every firm cannot exceed its own productive capacity; (3) the assignment of activities to firms must be univocal. The model is a classic MILP problem and can be solved by means of suitable algorithms (Marlow, 1993).

Instead of seeking a solution for the model written in this form, a different way of writing the variables is adopted which could lead to the desired GT model. The decision variable is a three-dimension matrix of



A. Villa et al.

unknown integers and it is an incidence matrix. One dimension can be collapsed by obtaining the matrices product-activities (**PA**), firms-activities (**FA**), firms-products (**FP**), which have the following definitions:

$$PA_{ij} = \sum_m x_{ijm} \quad ; \quad FA_{im} = \sum_j x_{ijm} \quad ; \quad FP_{jm} = \sum_i x_{ijm} \quad (4)$$

### 3.3. The analysis procedure

The objectives are the identification of networking patterns inside the existing cluster and the analysis of the activities allocations among the enterprises. It is possible to compare the existing allocation with the already defined networks in the real industry cluster. It is obvious that existing task allocation and existing network configuration have been assigned by the spontaneous interactions among enterprises under conditions of information asymmetry.

The new issue is now to understand if the composition of the network which solves the problem (1) is similar or different from the existing industrial structure. Applying methods borrowed by the production flow analysis to the design of the grouping of enterprises in cells, namely the supply chains, on the basis of production flow similarities, one can compare the industrial solution with the network organization resulting from the PFA analysis and highlight the differences between the two. Reasons for the differences can be due to three main aspects:

- the official supply chains are aggregations among firms linked by contracts and restrictions which could overcome the real supply chain as it emerges from the analysis of production flows;
- the agents inside the networks suffer by information asymmetry, because usually information is passed only between two adjacent nodes of the networks and therefore the chosen supply chain is poorly designed;
- the model cannot take into account the history of the network, some geographic peculiarity, like national borders, lack of proper connections and economic issues, like labour cost which could make convenient the participation of a firm to a supply chain in which presently it sell a smaller percentage of its production, leaving behind a more proper supply chain.

The latter is the case of many suppliers in the automotive supply chains. Generalized delocalization of production, combined with a lower labour cost in the Far East countries forced many suppliers to join supply chains on the very other side of the Earth, despite the costs and the coordination issues consequent to such large distances.

In a typical case study, two set of data are easily obtained:

- for each product family, the process plan;
- for each firm, the activities which it can execute.

The data correspond to the a-priori knowledge of two incidence matrices: **PA** and **FA**. Starting from the two matrices, the matrix **FP** can be simply obtained by:

$$\mathbf{FP} = \mathbf{PA} \otimes \mathbf{FA}^T \quad (5)$$

In other words it is the logic product of the matrix **PA** for the transpose of matrix **FA**.

## Extending Group Technology to the identification and the analysis of enterprises networks

Now it is possible to apply a Cluster Identification Algorithm (CIA) like the one proposed in (Kusiak, 1992) which extracts from the matrix the sub-matrix non interconnected or weakly connected. The results are the following.

- By applying the CIA to the matrix **FA**, ‘complementary islands’ are found inside the industry cluster when the matrix is diagonalizable. With the term ‘complementary islands’ they are meant a set of enterprises which execute the same productive activities
- Possible supply chains are isolated by clustering the matrix **PA**.
- By clustering the matrix **FP**, the sub-matrices obtained are the supply chains, or more generally the networks, actually present in the industry cluster.

It must be remarked that the networks found with this analysis are group of enterprises which have a real interchange of activities with each others and which have the productive capability to answer to the network requests. They can be utterly different from the networks which have been established on the field and which are confirmed also by contractual agreements. The method therefore should be applied in comparison with the real situation in order to find the ‘should be’ and the ‘should not be’ networks. The first term indicates the networks of enterprises which are not bounded together by a contract but which behave as if they were. On the other side a ‘should not be’ network is a network explicitly defined but without sound relationships among the component enterprises.

#### 4. Example of identification and analysis of a network

Suppose that the formal problem (1) stated in the preceding section has a solution in the form of the following Process Routing Sheet (PRS), see Table 1.

[insert table 1 here]

Lets every product be decomposed in a sequence of activities (process plan) and every activity be assigned to a different firm. From now on, for sake of simplicity the number assigned to an activity is representative of the matching firm too. The sequence is ordered and therefore from the PRS it is possible to follow the flow along the supply chain. Also the demand for every part is known but no information is available about lead times and costs. This is the typical kind of data which it is safely possible to extract from a cluster.

If every activity is executed by a different firm, the parts and the firms can be represented on an incidence matrix, where the non zero cells express the fact that the part is effectively worked inside the firm.

Figure 1 represents a Boolean incidence matrix for the Process Routing Sheet of Table 1 and contains, in addition to the **FP** matrix, the information about the inter-firm production sequence as well as the demand for every product and the workload for every firm. It is said augmented incidence matrix.

[insert figure 1 here]

The first problem to be solved is the identification of the “natural networks”, i.e. group of enterprises which act as a network independently from the existence or less of contractual bounds among each other. This is obtained by applying a CIA algorithm. The solution is not unique unless the matrix is exactly clusterizable.

In a nutshell, the cell formation strategy performs its objective, by finding the group of rows and columns which satisfy the following constraints completely or at the best.

- independency among different cells;
- singular cells should have a low demand in order to minimize the inter-cell flow;
- the sub-matrix dimension should be kept under control.



A. Villa et al.

A feasible solution is represented in Figure 2, with the “singular cells” highlighted in grey. In the classic theory of PFA the “singular cells” represent the parts which have to be worked by two different working groups or outside the factory through a subcontracting agreement. In our application the “singular cells” are not an issue, simply they represent the enterprises which belong to two different industry networks, which is the case of a firm whose production covers different market typologies.

[insert figure 2 here]

Therefore the method allows the recognition of three networks of enterprises, not strictly isolated each others. The first is composed by firms F1, F8 and F3, exchanging P3 and P5 within the cluster and P1 and P7 with the outside (with the third cluster in particular). The second network is composed by F2 and F6, exchanging P2 each others, while P6 is simply processed by F2 but not exchanged within the network. The third identified network is composed by F4, F5 and F7, exchanging P4 and P7 within the network it self ad with the first network as well, while P1 is processed by F7 for the first network.

Figure 3 represents clearly the relations among cluster composition and products exchanged among firms. Empty lines and columns point out respectively firms receiving (providing) products only from (to) the network outside, see F2 and F6. Table 5 represents the starting point for the production flow analysis reported in the following.

[insert figure 3 here]

A further kind of analysis could arise from the PFA approach, referring specifically to the role of each firm within its cluster. According to the conclusions derived by (Bergman, 1999) from statistical correlations, Figure 3 allows to recognize in a simpler way two types of enterprises and, depending on their distribution, two types of networks organization structure as well.

Enterprises could be differentiated in primary and secondary according to their relative weight in their network of interactions. Primary enterprises are characterized by a larger incoming or out coming flow within the network and with respect to all the others firms (said secondary). A network could be composed by a single primary enterprise and a set of secondary ones, or, as in the first network of the example presented in the previous chapter, by a primary link, that is two (or possibly more than two) enterprises exchanging the larger percentage of the cluster flow (F1, F8 in the example). The primary enterprises have usually the bigger production capacity in the network and probably they also manage the link with other clusters, when they exist.

Some hypothesis about the organization structure of the network could be derived. The organization structure refers to the decision-making processes in the administration of the network (who takes decisions? who decides the volumes exchanged, the prices?). When a single primary industry exists, the network has a hierarchical organization, while in the second case his structure is said polycentric. When, on the contrary, no significant difference can be recognized in the flows incoming and out coming from firms belonging to the network, the network itself is said canonical (the theoretical definition of the three type of network is due to Samarra, 2003).

In a hierarchical network the primary firm plays the role of main coordinator and leader of production, distribution and innovation processes. Secondary firms work in single-commitment way, and their existence depend on the primary industry capability of gaining market share nearby the end customer. The potential role of public institutions in supporting this kind of network is very narrow, at least until the secondary enterprises stay under the leader’s shadow.

## Extending Group Technology to the identification and the analysis of enterprises networks

In a polycentric governance structure each primary industry is called to coordinate itself with both its sub-network of secondary partners (in the simple exemplification F8-F3) and with the other primary firms (F1-F8). This type of organization typically characterizes products with a high degree of technological features, where the cognitive partition of the labour is crucial. The role of public organizations could be significant in assisting the primary firms in their role of multiple coordinators.

The canonical cluster refers to the typical DESNET structure. It is composed by a network of demand and supply relationships centred on the production of the same type of end-product. The network is nearly balanced, sufficiently open to the outside, highly socially and territorially characterized, and neither strong nor formal relationships exist among firms. They are rather put together by habitual links strengthened by the physical and cultural closeness. Typically these networks produce high quality products deeply correlated to the resources (both material and not) available in the region. Public institutions have the crucial role of defending the tricky existence of both productions and enterprises assisting them in critical matters of intellectual property, trade marks, marketing and innovation (assisting, for example, the creation of a common laboratory of research or technological consulting).

The organizational structure deduced or recognized with this method must be necessarily supported by other considerations, taking into account the historical and social skill of the network, the cognitive organization of work, and different interdisciplinary aspects.

## 5. Conclusions

In this paper a sustainable method for the identification of network of firms is proposed. The procedure need the only information about the production flows among a set of firms and is based on the GT method.

A mathematical formulation of this traditional method is introduced in order to apply it to the new environment composed by a network of firms. A heuristic way to get a solution is then provided.

The aim is not to find the optimal solution, but to have a practical tool to recognize a network structure in a given group of firms already interacting and to compare it with the existing one. The differences could be caused by social or political issues, or they can depend of a wrong awareness of the network structure and organization. In the latter case the method could open the road for significant improvements.

A practical example shows how the tools works with a simple scenario of 8 firms exchanging 7 products and which degree of analysis could be reached. Not only the identification of the network is simply feasible, but also, taking advantage of other analytical and theoretical studies coming from different disciplines, the detection of potential or existing organizational structure is practicable.

Further development are overseen in order to propose the method, properly supported by social, economical and political considerations, as an investigation tool supporting public bodies (e.g. regional governments) in identifying and assisting existing or potential industrial networks.

## 6. Acknowledgments

This research has been partially supported by the Italian Ministry of Education, University and Research, within the national-interest research programme PRIN number 2004090012. Furthermore the research has been developed in the framework of the EU Coordination Action (CA) CO-DESNET, project n° IST-2002-506673.

## References

Albino V., Izzo C., Kühtz S., Input-output models fro the analysis of the local/global supply chain, Int. *Journal of Production Economics*, 2002, **78**, 119-131.

A. Villa et al.

- 1  
2  
3 Albino V., Kühtz S., Enterprise input–output model for local sustainable development—the case of a tiles  
4 manufacturer in Italy, *Resources, Conservation and Recycling*, 2004, **41**, 165-176.  
5 Beccattini G., Industrial District and interfirm cooperation in Italy: The Marshallian industrial district and the  
6 socio-economic notion, *Int. Ist. Labour Studies*, 1990, 37-51.  
7 Bergman Edward M., Feser Edward J., *Industrial and Regional Clusters: Concepts and Comparative*  
8 *Applications*, Regional Research Institute, West Virginia Univ., Morgantown, USA, 1999.  
9 Bogataj M., Bogataj L., Vodopivec R., Stability of perishable goods in cold logistic chains, *International*  
10 *Journal of Production Economics*, 2005, **93**, 345–356.  
11 Czamanski S., Ablas L.A., Identification of industrial clusters and complexes: a comparison of methods and  
12 findings, *Urban Studies*, 1979, **16**, 61-80.  
13 Doeringer P.B., Terkla D.G., Why do industries cluster? In *Business Networks: Prospects for Regional*  
14 *Development*, U. H. Staber et al. (Ed.), (Walter de Gruyter: Berlin), 1996.  
15 Enright, M.J., Regional clusters and economic development: A research agenda, U. H. Staber et al. (Ed.),  
16 (Walter de Gruyter: Berlin), 1996.  
17 Faratin, P., Sierra, C., Jennings, N. R., Negotiation decision functions for autonomous agents, *Robotics and*  
18 *Autonomous Systems*, 1998, **24**, 159-182.  
19 Kusiak, A., Branching Algorithms for Solving the Group Technology problem, *J. Manufacturing Systems*,  
20 1992, **10**(4).  
21 Marlow, W.H. , *Mathematics for operations research*, (Dover, New York), 1993.  
22 Rosenfeld S., *Industrial Strength Strategies: Regional Business Clusters and Public Policy*, (Washington DC:  
23 Aspen Institute), 1995.  
24 Samara, A., *Lo sviluppo nei distretti industriali, Percorsi evolutivi fra globalizzazione e localizzazione*,  
25 (Carocci,Roma), 2003.  
26 Sangwon Suh, Functions, commodities and environmental impacts in an ecological–economic model,  
27 *Ecological Economics*, 2004, **48**, 451– 467.  
28 Simchi-Levi, D., Kaminski, P., Simchi-Levi, E., *Designing and managing the Supply Chain – Concepts*  
29 *Strategies and Cases Studies*, (McGraw-Hill), 2000.  
30 Verwaal, E., Hesselmans, M., Drivers of Supply Network Governance: An Explorative Study of the Dutch  
31 Chemical Industry, *European Management J.*, 2004, **22**, 442-451.  
32 Distretti industriali italiani. Available online at [www.clubdistretti.org](http://www.clubdistretti.org) (accessed 2 December 2005).  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

Extending Group Technology to the identification and the analysis of enterprises networks

Table 1: Process Routing Sheet

Product	Activity list	Demand
1	1,7	100
2	2,6	1500
3	8,1,3	80
4	5,4,7	350
5	1,8	3400
6	2	200
7	4,7,8	200

<i>Firm</i> <i>Product</i>	F1	F2	F3	F4	F5	F6	F7	F8	<i>Demand</i>
P1	1						2		100
P2		1				2			1500
P3	2		3					1	80
P4				2	1		3		350
P5	1							2	3400
P6		1							200
P7				1			2	3	200
<i>Work-load</i>	3580	1700	80	550	350	1500	550	3680	

Figure 1. Augmented incidence matrix corresponding to the PRS of Table 1.

<i>Firm</i> <i>Product</i>	F1	F8	F3	F2	F6	F4	F5	F7	<i>Demand</i>
P3	2	1	3						80
P1	1							2	100
P5	1	2							3400
P2				1	2				1500
P6				1					200
P4						2	1	3	350
P7		3				1		3	200
<i>Work-load</i>	3580	3680	80	1700	1500	550	350	550	

Figure 2. Network identification matrix.

A. Villa et al.

<i>Up-Firm</i> <i>Down-Firm</i>	F1	F8	F3	F2	F6	F4	F5	F7	<i>Incom.</i> <i>Flow</i>	<i>(from</i> <i>outside)</i>
F1		P3							80	
F8	P5							P7	3600	(200)
F3	P3								80	
F2										
F6				P2					1500	
F4										
F5							P4		350	
F7	P1					P4, P7			550	
<i>Outcom.</i> <i>Flow</i> <i>(to outside)</i>	3580 (100)	80		1500		430	350	200		

Figure 3. Production Flow Analysis of the Network

Peer Review Only

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60