Co-operative production planning for small- and medium-sized enterprises

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Abstract

Minimising manufacturing cost and production time parallel to raising the quality and the shipment reliability are important challenges in every production system. In case of distributed production systems the management of the above-mentioned criteria has great significance and needs a complex, co-operative handling of the problems. A new, co-operative manufacturing network model is proposed for co-ordinating the production of Small- and Medium-sized Enterprises (SMEs), based on the holonic paradigm. The paper introduces the main modules of the model succinctly and describes an application under realisation in Hungary, in an agricultural SME network, pointing its economic benefits as well. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

On the present level of market competition, enterprises have to organise themselves into effective production system architectures in order to be able to fulfil the market demands. These system architectures can be realised only by using computer networks for production management in order to co-ordinate the production of the distributed manufacturing units.

There are different approaches, different names (agile, biological, fractal [1], holonic, etc.) for production-, or manufacturing systems that basically cover the same idea: a flexible network of co-operating autonomous manufacturing units. The holonic manufacturing system is an approach for a theoretical framework for autonomous and decentralised manufacturing organisations based on the classical holonic theory introduced by Koestler [2].

The holonic production system is a system of co-operating holons that are organised to achieve a production goal. This system integrates the whole range of activities from booking the orders through design, production and marketing to form an autonomous and decentralised production organisation. According to the holonic organisation paradigm the manufacturing environment is going to transform itself into a holonic system as...
openness, flexibility and similarity in building blocks are vital advantages. The virtual enterprise is a practical instantiation of the holonic paradigm in the form of a multilayer, open, flexible (through continuous, dynamic re-configuration) network.

The structure of a virtual enterprise can be seen as a holarchy, i.e. it is a temporary, goal-oriented aggregation of several individual enterprises. Each virtual enterprise is created to pursue a specific business objective, and remains in life as long as this objective can be pursued. After that, the individual nodes resume their independence from each other. The resource of a node that was previously allocated to the expired business is re-directed toward the node’s individual goals, or toward other virtual enterprises.

The original virtual enterprise (VE) model has been developed for decomposing large companies that have enough financial, human and organisational resources. The decomposition is based on functions that can result in replications across the network.

In the Planning Small–Medium Enterprise Networks (PLENT) project (ESPRIT Project No. 20723) a more practical, more appropriate approach of the virtual enterprise has to be realised for Small- and Medium-sized Enterprises (SMEs). For the customers the network reflects the framework of a big company, a big economical organisation which can provide complex products associated with bigger capital and professional knowledge, while the basic functions of the SME that are important for their independence remain intact. In such a distributed manufacturing environment the production planning has a key role. The co-ordination of the orders, the optimal assignment of the different resources in a co-operative production of several SMEs is a very difficult task.

The SME network development work is done in the framework of the PLENT project with the participation of firms from Italy, Greece, Hungary and Spain. The main goal of the project is to support organisations that manufacture mechanical parts and products in SME-like production environments.

The paper introduces this management philosophy and the network model briefly then describes a special application of the manufacturing network model for agriculture production (oil and seed production).

2. The SME Network

2.1. “As-Is” characteristics of SMEs

Several geographic regions can be characterised with special industrial organisational structures called SME. These SMEs are well-known for their dynamic behaviour, but their prosperity, and sometimes their existence, is continuously exposed to risks of the limited investment capability, the difficulty of diverting skilled personnel from day-by-day activities, to undertake process re-engineering initiatives and to the lack of advanced planning support tools specifically conceived for them. Because of these reasons it is really a hard problem for the SMEs to give proper answers to market challenges. The co-ordination of the different SMEs' production in the case of producing a product jointly generates similar problems as in the case of large firms, but the solution is different [3].

SMEs seem to be appropriate units to behave like network nodes because of their lean structure, adaptability to market evolution, active involvement of versatile human resources, ability to establish sub-contracting relations and good technological level of their products. One negative feature of the co-ordination is the traditional individualistic attitude of SMEs. This attitude leaves each enterprise completely alone in facing marketing, purchasing, design, engineering and technological innovation problems. In addition, other problems arise from historical distrust between enterprises traditionally in competition with each other.

These observations are confirmed by the requirements analysis carried out in Task 1.1, and documented by Deliverable D1 of the PLENT project [4]. Some of the examined SMEs are, or have been involved in distributed manufacturing experiences, but their attempts have not until now produced the expected benefits. This is mostly due to the lack of a co-operation model allowing the different nodes to behave as a whole, at the same time preserving their autonomy. Studying and realising this model, along with the software tools required
for its implementation are the main objectives of the PLENT project.

2.2. “To-Be” characteristics of SMEs

When SMEs intend to imbalm their basic characteristics and develop their competitive abilities at the same time it may lead to contradictions. A solution for this problem can be a well-organised co-operative network, that takes into consideration the mismatching agents and tries to find a close-to-optimum solution in this turbulent environment.

In a distributed manufacturing environment the production planning has a key role. The co-ordination of the orders and the optimal assignment of the different resources is a very difficult task in a co-operative production environment of a closed group of several SMEs. The main characteristics that have to be preserved are the independence of nodes (SMEs) and the stability of the network.

All PLENT nodes have to be involved in the manufacturing process on an “equal-rights” basis. Thus, one of the major requirements for network co-ordination is the availability of information and methods for workload distribution among the nodes. It requires methods and tools for distributed production planning.

The network has to be stable in time which means that the network products, processes and management policy is the same for longer periods. The main result of this stability is that the costs and complexity of network creation and modification will be low. Individual nodes can join or leave the network, but this must be considered as a persistent structure.

Taking into consideration the basic conditions listed above, the PLENT project has to apply an approach which is nearly opposite to that of the virtual enterprise, i.e. the pure holonic approach had to be modified. While the network can be assumed to be persistent in time, production phases performed by each node have to be co-ordinated and planned at the network level, taking into account the requirements and constraints placed by all nodes.

To this purpose a network co-ordinating unit is required, intended as a stable production management structure which distributes and controls tasks performed by all the nodes. To play its role, the co-ordinating unit needs accurate and constantly updated information on the distributed process phases, capacity and performance of each node, transports between the nodes, and workload distribution policies.

These data cannot be found in any node’s local information system. Thus, to ensure proper network operation, a global knowledge-base must be constituted with data, constraints and criteria defined jointly by all nodes. This represents one of the most innovative features of the PLENT approach.

From the aspect of enterprise modelling, the PLENT network can be handled as a production system on business level of integration where enterprise-wide knowledge sharing and business process co-ordination are existing in everyday practice [5].

In consideration of the requirements expressed by SMEs, it is possible to compare the PLENT idea of virtual enterprise with that currently derived from the holonic theory. This allows to determine if and to what extent the current virtual enterprise approach can be applied to the PLENT network [6]. Of course there are other realisations of VE that fulfil other different VE functions [7,8]. Indeed, a number of properties commonly attributed to the virtual enterprise are no longer valid when transferred to the PLENT organisation model. The most significant differences between the two approaches are summarised in Table 1.

Having in mind the above distinctions, the PLENT network can still be considered as a special case of virtual enterprise organisation. With respect to traditional co-operation models, the PLENT network has the following distinctive features:

- The network results from the aggregation of a number of independent, small-medium enterprises.
- The network is constructed and organised to reach a well-defined, long-term objective, common to all member enterprises (e.g. designing, constructing and selling a certain family of products).
- The network nodes have basically equal rights regarding the definition of network policies and exploitation of joint business opportunities.

In conclusion, the PLENT project focuses on distributed production management in a stable
network of co-operating SMEs. In an SME network, there is a strong need for a network model that is based on a planning strategy [9]. Another important goal during the software development is the product independence, i.e. the network model has to be general enough, to be able to apply it in a wide range of different products, in different production environments.

2.3. Network model for co-operative production planning

The network model contains different knowledge elements resulting in a global information base (data, information, knowledge) shared by all nodes. The network co-ordination is based on this information base. The most important of these elements is the description of the network distributed process, in terms of phases carried out by the different nodes to reach a common objective.

The network model contains the event trace diagrams (e.g. for describing different communication scenarios among system entities), the data-flow diagrams (used for describing functions representing processes carried out by nodes and the co-ordination unit inside the network), state transition diagrams (describing the dynamic behaviour of system entities depending on the events that reach the entities). The description of system entities (co-ordination unit, nodes, customer – external connection of the network) and the basic process models are also elements of the information base.

The Network Operational Scheme (NOS) is applied for the description of the process models. An NOS is defined by the sequences of all production and transfer phases required to obtain a given product. NOS can be conveniently represented as an oriented graph where nodes represent manufacturing and transfer phases and arcs represent precedence links between subsequent phases.

An NOS has two sets of parameters: the phase functional parameters that are local to a given phase and define different options for that phase output, and the NOS configuration parameters that represent optional and alternative phases. NOS generation, NOS modification, plan generation, forward planning and backward planning are some of the typical NOS processes.

In order to achieve the required network timeliness and co-ordination neutrality, the PLENT network organisation must be supported by explicitly designed planning tools. In particular, three software modules are required: a co-ordination module, a local planning module and a performance evaluation module.

- Co-ordination module (CU)
The co-ordination module realises the network planning policy. The co-ordination module is responsible for controlling the connection outside the network, for keeping the contact with the customers, for selecting the proper nodes (production units) and for distributing production tasks to them.

- Local planning module (LPM)
The local planning module supports the network-related activities in charge of each node, aimed at managing and communicating delivery plans and delivery conditions with the co-ordination unit and the supplier and client nodes. The local planning modules realise the network controlling tasks of the node, in order to fulfil the goals of the management and communication, and deliver the status information of the node for the other nodes.

Table 1
Significant differences between the VE and the PLENT approach

<table>
<thead>
<tr>
<th>Main characteristics</th>
<th>Virtual enterprise</th>
<th>Co-operative network of SMEs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basis for fast reaction</td>
<td>Functional specialisation</td>
<td>Inherited flexibility</td>
</tr>
<tr>
<td>System organisation</td>
<td>System duplication</td>
<td>Identity preservation</td>
</tr>
<tr>
<td>Aggregation</td>
<td>Temporary</td>
<td>Stable</td>
</tr>
<tr>
<td>Co-ordination</td>
<td>Local</td>
<td>Global</td>
</tr>
</tbody>
</table>

Performance evaluation module (EM)

The performance evaluation module is used by the co-ordinating unit to calculate node reliability starting from measures of their past behaviours, and network reaction capability by simulating possible scenarios. The performance evaluation module supports the work of the co-ordination unit in selecting the best node for fulfilling a task. This node generates different measures, statistics and estimations based on the past behaviour of the nodes.

3. The Hungarian network

Based on the PLENT VE approach, four different national networks are under development: the Italian, the Greek, the Hungarian and the Spanish SME network. The product profile of each national network is different, demonstrating by this fact that this type of virtual manufacturing approach can be applied flexibly under different circumstances. In the following sections the main characteristic and the organisation of the Hungarian Network will be presented.

3.1. Characteristics of the Hungarian network

The main activities in the Hungarian Network (HN) are financing oil seed growing on plantations, seed-oil production and trading with the products which are the seeds and the seed-oils. The products as physical objects are seeds, seed-oils and contracts for production with farms and factories, and contracts for trading with trading houses. The market for the products is in Hungary and abroad. The main functionality is contracting partners to produce and to sell and buy. There is a management and a staff to prepare contracts using advanced forecasting and trend analysis tools. The product delivery cycle is unique: no cycle for the contract, however there is a special cycle for the seeds and oils covered by the contracts, as financing starts very early, 3–12 months before harvesting.

The HN is a rigid, not dynamic, relatively simple network. The main processes are connected to environments basically controlled by the nature (seed growing), or have a very simple sequential technology (oil-pressing). Because of these reasons there are only a few possibilities to modify technology routes, phases of the products (seeds, seed-oil, contracts). The range of each product group is narrow as well. This means that there are about five different types of seeds, two types of oil, and a limited number of different contracts.

In the HN in some cases there is no possibility to “manufacture” the part again that becomes a waste, and each order has a great value. The order is very big (thousands of tons), needs a long time to fulfil, there can be sudden, not “repeatable” events, it is not easy to cancel an order by the customer, nor by a node. The network has to handle (compensate, balance) highly uncertain events with high reliability.

3.2. The Hungarian network model

The co-ordination module for the HN is an Investment Co. Its main fields of activity are financing oil seed growing on plantations, seed-oil production and trading. The products of the Investment Co. are contracts, i.e. pieces of signed papers, for financing growing and production of seeds and oils and to sell and buy them.

The evaluation module is an independent software node in the first pilot implementation.

There are three different profiles of individual nodes in the network:

1. Big farms and oil-pressing factories. Their activities include market research, approval, contract preparation, contracting, growing the seeds on the plantations and delivery of seeds or pressed oils.
2. Small farms and seed producers. Their activities are basically the same as above.
3. Trading houses. Their activities include the seed and oil purchasing, the selling of the purchased goods and cashing of the money.

The top-level functional description of the Hungarian SME network for seed and oil production and marketing can be seen in Fig. 1. For detailed
description and analysis of the HN, please see in Deliverable D02 [10].

3.3. Planning requirements of the HN

The HN is a real-time, on-line network with three basic functions. The intelligence of the Hungarian network is supported by expert systems (ES) in the CU and EM. The CU and the EM software may be included into any of the nodes, or they may be independently implemented, an LPM must belong to all participating nodes. The tasks of the expert systems are double: they solve the planning problems of the network and in parallel handle/control the complex communication among the CU and the EMs.

Before starting the ES development, the planning requirements for the ESs have to be investigated very carefully, in order to avoid critical problems later.

3.3.1. Planning requirements for the co-ordinating unit

- Subcontracted seed and oil production orders monitoring
  It is important for the co-ordination unit to be able to consult in any moment the list of the production order launched for a given order. In addition it shows all the associated data with each order, as the following: start date, forecast delivery, progress state of the work, etc.

- Node workload monitoring.
  The co-ordination unit can see in any moment the forecast workload for each node for a period of time. This information is very important for the workload distribution among the nodes. In order to get this, it is necessary to update periodically the information used by the co-ordination unit.
Monitoring of the accepted and pending subcontracting offers.
The co-ordination unit requires to have a list of the subcontracting offers for each special product and partner. So the co-ordination unit should control the state of each offer, like: accepted, pending of acceptance, to be sent to the node.

Sending of the planning of the subcontracted groups to the nodes for their fulfilment.
The node needs to receive the current information and the group planning. The co-ordination unit defines some milestones. The node would establish the milestone’s date and this information would return to the co-ordination unit.

Linking between the co-ordination unit planning and the node planning.
The co-ordination unit divides the planning into some activities. These activities might be used in the node planning, so they could be controlled from the co-ordination unit which should know the manufacturing progress. This information exchange might be in an electronic environment or similar. So each time the co-ordination unit connects with a node it is getting the last updated information.

Task distribution and task assignment criteria. As it was mentioned above, in principle all nodes are capable of accomplishing any of the production tasks. Due to historical reasons and work sharing it is normal to have a distribution as not all partners have oil-pressing facilities among producers, and the trading houses are different in relations and in their main lines (special seeds, or oils, or both).

Workload distribution. The workload distribution is accomplished when the needs calculations are performed. This is the moment when the seed growing, oil production and marketing launches for each group are assigned. The local planning task is made using different methods (not necessarily computerised) at different sites.

3.3.2. Planning requirements for the nodes

• Forecasting, trend and market analysis.
The co-ordination unit and the node’s computer systems are similar, so it is interesting to have a more automatic information exchange method. The first application for this automation might be the exchange of the forecasting and analysis data from the co-ordination unit to the nodes. With this automation some actual steps could be avoided and some benefits might be obtained like: paper reduction, reduction in the time required for information entry, less writing errors, etc.

• Access to the co-ordination general planning in order to foresee the workload.
After making the first planning from the co-ordination unit this information might be sent to each node telling them the potential production/trading needs and the estimated dates. With this information the nodes might foresee their necessary production/trading for a period of time. One benefit of this policy would be that the nodes would avoid or would reduce some bottlenecks in their production.

• Anticipated prevision of the potential orders and workload.
This point would be a consequence of the previous point.

• Group design evolution in the co-ordination unit.
If the node knows in advance its workload, the node might take some information from the co-ordination unit about the state of the design activities related with the product group it has to produce. So depending on the design state, the node might foresee potential delays in the preparation and re-planning of its local planning.

• To dispose a local planning tool with a finite capacity.
It might be interesting in order to optimise the workload.

• To define the verification cards between the co-ordination unit and the nodes.
The co-ordination unit sends to the nodes all the required information about the production group. Besides the co-ordination unit sends to the nodes a verification card, where it defines the verification requirements. So the node might participate in the verification card definition in order to optimise the quality process.

In Table 2 a few rules/actions are introduced for re-planning the original production plan in case of special, unscheduled events (problems).
Table 2
Some selected rules/actions for re-planning the original production plan

<table>
<thead>
<tr>
<th>Problem</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>The node refuses the appraised offer</td>
<td>(1) Subcontract to another node</td>
</tr>
<tr>
<td></td>
<td>(2) Make new offer appraise</td>
</tr>
<tr>
<td></td>
<td>(3) Production subcontracting to other nodes, out of the network</td>
</tr>
<tr>
<td>The node cannot finish the work on time</td>
<td>(1) To urge the node in order to finish the work on time</td>
</tr>
<tr>
<td></td>
<td>(2) Depending on the final evolution</td>
</tr>
<tr>
<td></td>
<td>(2.1) suppose no perturbation in the final business, the activity is re-planned</td>
</tr>
<tr>
<td></td>
<td>(2.2) suppose perturbation in the final business, the activity is re-planned and the customer is advised and explained the reasons and the future actions</td>
</tr>
<tr>
<td>The node’s supplier is out of the delivery time</td>
<td>(1) Ask the customer to urge the supplier in order to supply on time</td>
</tr>
<tr>
<td></td>
<td>(2) Ask the co-ordination unit to urge the supplier in order to supply on time</td>
</tr>
<tr>
<td>Customer modification</td>
<td>(1) Re-negotiate with the customer</td>
</tr>
<tr>
<td></td>
<td>(2) To communicate to the nodes</td>
</tr>
<tr>
<td></td>
<td>(3) Project re-planning</td>
</tr>
<tr>
<td>Disfunction on the production groups</td>
<td>(1) If it is very expensive, advice to the node in order to reorganise it in the co-ordination unit</td>
</tr>
<tr>
<td></td>
<td>(2) If it is simple, it is reorganised by the co-ordination unit</td>
</tr>
</tbody>
</table>

3.3.3. Communication and information exchange

In the case of a planning network the definitions of the regular communication relations and routes in the design phase of the network are very important. Table 3 shows part of the communication and information exchange requirements with the following assumptions:

- there is no communication between production and trade nodes, they communicate only with the co-ordination unit,
- the customer has no direct contact with the production and trade nodes, only with the co-ordination unit,
- the co-ordination unit is the investment Co. in our special case (as soon as an independent co-ordination unit will be established it would be changed to a more special local node).

(Information exchange is really bi-directional in most cases, this is shown by multiple arrows.)

3.4. Differences in HN from other national PLENT networks

Some of the main characteristics of the HN are listed in Section 3.1. In the HN there are several activities, conditions, methodologies that are different from the ones used in the other national networks. These differences have to be taken into consideration while building the network model as well. In the following some of them are listed.

Timing: The critical factor in the HN is the timing. There are big shifts among the different production phases and big differences in the duration of the phases. There is a magnitude difference between production phases duration (e.g. contract preparation – 6 days, seed growing – 180 days) and between the two sequencing phases there is a 180–360 days gap, shift. This time characteristic results in special needs in the network management. The administration process is fully separated from the flow of materials in time, that means, the contract preparation and asking credit from banks take place 1/2–1 year before the seed growing (SG) or/and the oil pressing (OP). The resource allocation and scheduling of activities (phases) are based on the actual information (at the time of contracting) that may be different from capacities during the realisation (at the time of SG, OP). Originating from these characteristics it is important to have a three-level planning possibility for the co-ordination unit:

- long-term planning (breadth-first),
- medium-term planning,
Table 3
A part of the information exchange among the nodes and the CU

<table>
<thead>
<tr>
<th>Document</th>
<th>Customer</th>
<th>Co-ordination unit</th>
<th>Production node</th>
<th>Trade node</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consult</td>
<td>==</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standards</td>
<td>==</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offer</td>
<td>==</td>
<td></td>
<td>==</td>
<td></td>
</tr>
<tr>
<td>Order</td>
<td>==</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demand</td>
<td>==</td>
<td></td>
<td>==</td>
<td></td>
</tr>
<tr>
<td>Supply</td>
<td>==</td>
<td></td>
<td>==</td>
<td></td>
</tr>
<tr>
<td>Planning</td>
<td>==</td>
<td></td>
<td>==</td>
<td></td>
</tr>
<tr>
<td>Accepted offer</td>
<td>==</td>
<td></td>
<td>==</td>
<td></td>
</tr>
<tr>
<td>Rejected offer</td>
<td>==</td>
<td></td>
<td>==</td>
<td></td>
</tr>
<tr>
<td>Order</td>
<td>==</td>
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<td></td>
</tr>
<tr>
<td>Product</td>
<td>==</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity</td>
<td>==</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forecast</td>
<td>==</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Contract</td>
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</tbody>
</table>

- operational planning in case of disturbances, re-planning.

The products of the Italian network (IN) are mechanical components that have about one month production cycle time. The HN has more similarity to the Spanish network (SN) which produces special machine tools with about nine months production cycle time.

Order selection. Other PLENT networks use depth-first planning while in the HN the breadth-first planning method is in use in the long-term planning. First the capacities of all seed growing nodes (farmers) are planned then the capacities of all oil-pressing factories. The contract preparation and trading phases are not really significant from this aspect. Because of the large time shift between contracting SG and OP during the realisation some problems may arise. In such cases an operative re-planning is needed using the actual existing free capacities. Priorities during the planning are important. Product quality and node (farmer) reliability are very important in capacity selection.

Phases assignment. Phase due dates have different importance with different levels of uncertainty. Contract preparation has very low uncertainty with exact dates, while e.g. SG phase has high uncertainty, so needs flexible dates. In the other networks the production is far more calculable.

Importance of storage. Using the storage for balancing the peaks/gaps of production is vital in the HN. The storage of seed can belong both to the SG phase and to the OP phase. There is a competition among the nodes to avoid seed storage because of the high costs and the risk of rotting. On the other hand, OP nodes are interested in having a minimum stock of seed in order to have a safe continuous production. The final product – oil – is delivered as soon as possible without storage. To calculate with stocks on the network level by the co-ordination unit does not fit into the original PLENT approach. In machine industry PLENT production aims at the JIT approach to minimise storage. Stock management is planned to be handled by each node separately, but in the HN there is need for a hybrid solution in order to have high-level information for the co-ordination unit about seed stock levels. The node fulfilment index has to be re-interpreted in the case of the HN. “Daily” time-spans, exact, fixed dates are hard to interpret in some cases in the HN (because of the uncertainty).

3.5. Realisation of the Hungarian network model

The first step of the realisation of the Hungarian network model was to start a pilot network project. The main goal of the Hungarian Pilot Network
(HPN) project was the application of the ideas and results of the PLENT project in a Hungarian network. The communication architecture of the HPN is a WAN, based on ISDN carrier and network service. The HPN has been implemented between geographically separated company locations between the CIM Research Laboratory and three partners who are dealing with seed- and seed-oil production and trading.

The communication is based on the client–server philosophy. On all of the locations a network node has been installed. The CIM Laboratory and Partner I. nodes are LAN servers, the other nodes are standalone personal computers. The communication between the nodes are realised with the help of the Hungarian Public ISDN network service. The ISDN basic rate and primary rate accesses (ISDN2 – ISDN BRA, or ISDN30 – ISDN PRA) ensure transparent digital connections for the subscribers.

As the hardware tool of the ISDN network access, ISDN adapters are developed and used for personal computers. The logical access and the network integration is provided by Windows NT, Windows NT RAS and Translan Remote Access Service for NT. The user interface, the frame system which integrates the applications is a Windows-based operating system or GUI (NT workstations) as the applications run on the nodes conform to the windows conventions.

During the development of the software, important aspects were the transparency, the platform independence, flexibility and expandability. The realisation of the SW took place by using the Microsoft Visual C++ tool-case. The data-base server runs on the Sybase 11 Sql server. The program design and realisation mapped two main fields; the first was the object library that maps the program structures, the second one was the development of database plans. The realisation of these two fields took place with the object-oriented design and information modelling techniques.

The information models (conceptual and physical information models) have been developed by Sybase DataArchitect. Using this package the modification of the models is very easy. As an example, the conceptual information submodel of the production process is shown in Fig. 2.

4. Benefits of the co-operative network

In most cases SMEs have limited financial and human resources, usually they have no advanced planning support tools that are essential for a traditional (fully open) VE. There is also a historical background namely the traditional individualistic attitude of SMEs. This means facing the marketing, design, engineering, technological innovation and purchasing problems alone. Handling the SME network as a limited number of independent nodes, the network approach has the following general advantages:

- More complex and technologically advanced products can be realised by connecting/integrating skills and design capabilities of the network nodes.
- Higher manufacturing volumes can be obtained by cumulating node capacities, especially if two or more nodes concur in performing the same manufacturing phases.
- Fluctuations of market demand volumes can be handled better by sharing workload peaks and shortages among the network nodes.
- The limited resources of each SME can be better spent on technological innovation and process re-engineering rather than in hard competition with other SMEs.

The financial advantages of a co-operative network converge to the gains given by Jim Browne in [11] as the main characteristic of a production management system “Beyond MRP II, JIT and OPT”. Decomposing and analysing the above-listed benefits from the viewpoint of the HN, the main advantages are the more effective usage of each SMEs (farms, oil-pressing factories) resources, the faster reaction for market demands while keeping the individual characteristic of each node (farm).

As the stock and transportation costs decrease, the production will need less investment. Taking into consideration the very big amount of production (hundreds of tons) these savings can result in considerable amount of money.

Through the co-ordination of the production in a very unstable, unreliable (working with high risk) production field, the agricultural production can
become more reliable, more safe both for the customer and the farmers who are members of the network. The reliability results in more orders, stabilised and higher income, less costs, i.e. more profit.

The stabilised production will result in increasing credit standing, that is also important for the farmers, as most of them need credit to start their production cycle.

The expected costs of the network investment (network installation and software) are low, to learn the applied information technology one needs only short time, so the PLENT manufacturing network has good chances for success in the agricultural field as well.

5. Conclusions

In the PLENT approach, which is a practical modification of the original holonic paradigm for SMEs, the network is conceived as a set of operational nodes (SMEs) with equal rights, co-ordinated by a central unit that interacts with customers, distributes tasks to nodes on the basis of prefixed criteria and up-to-date information on node state.
and reliability. This central unit informs each node on its position in the network with respect to the manufacturing process and also tries to solve possible network perturbations. The nodes are responsible for executing the assigned tasks within given time intervals and, to this purpose, they maintain direct relations with the respective suppliers and clients.

This new approach for SME network co-ordination is very promising, because it offers the advantages of the holonic manufacturing paradigm giving the possibility, in parallel, of keeping the traditional individualism of SMEs. The realisation of the method is progressing in four countries involving SMEs from three different fields of production (in machine- and textile industry and in agriculture).

The experiences of the pilot realisations show that significant financial benefits can be gained as well. The results achieved prove that it is possible to develop a network-based co-ordination software for SMEs that is general enough to be applied in fully different production fields even in the very unpredictable field of agriculture.

References