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► **To cite this version:**

G Lo Nigro, Manfredi Bruccoleri, Giovanni Perrone. 18th ICPR paper: NEGOTIATION IN DISTRIBUTED PRODUCTION PLANNING ENVIRONMENTS. *International Journal of Production Research*, 2006, 44 (18-19), pp.3743-3758. 10.1080/00207540600575787 . hal-00512885

HAL Id: hal-00512885

<https://hal.science/hal-00512885>

Submitted on 1 Sep 2010

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| | |
|-------------------------------|---|
| Journal: | <i>International Journal of Production Research</i> |
| Manuscript ID: | TPRS-2005-IJPR-0521 |
| Manuscript Type: | Original Manuscript |
| Date Submitted by the Author: | 02-Dec-2005 |
| Complete List of Authors: | Lo Nigro, G; Università degli studi di Palermo, DTMPIG Bruccoleri, Manfredi; Università degli studi di Palermo, DTMPIG Perrone, Giovanni; Università degli studi di Palermo, DTMPIG |
| Keywords: | MULTI-AGENT SYSTEMS, PRODUCTION PLANNING, DISTRIBUTED RESOURCE PLANNING |
| Keywords (user): | |
| | |



NEGOTIATION IN DISTRIBUTED PRODUCTION PLANNING ENVIRONMENTS

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Abstract

Mass customization and global competition push enterprises to adopt proper business models able to capture all the opportunities arising from emerging competition rules. An increasing number of industrial enterprise distributes its production capacity world wide to achieve lower production costs, lower distribution costs (due to the higher closeness to customers), and deeper knowledge of customer needs. As drawback, coordination of the different production plants and the balance among plants and enterprise goals represent critical issue in the network management. In this context the paper faces with the production planning problem, adopting a traditional hierarchical time based perspective in the analysis of the global process and suggesting a decentralized planning approach to deal with the originated sub tasks related to different time horizons. In particular, the paper suggests a production planning architecture able to highlight relationships among sub tasks' variables in which mechanisms assure consistency among solutions of different planning levels. Moreover the paper proposes negotiation frameworks as effective tool to manage production planning sub-tasks.

Keywords: Negotiation, Distributed Production Planning (DPP), Multi Agent System (MAS)

1. Introduction

Mass customization consequences, such as shorter and shorter product life cycles and low-cost variety, have brought critical pressures to improve production efficiency, responsiveness to market changes, and substantial cost reduction. Some of these issues can be achieved through innovation related to production systems (Advanced Manufacturing Systems, Reconfigurable Manufacturing Systems,..) or to operations and organization coordination. Distribution of activities involved in a business process is a successful management expedient to face with current market characteristics; indeed, the need for global competitive strategies, for rapid response to market changes, for costs and time to market reductions, and for highly customized products, leads the enterprise value chain to be more and more distributed. This brings manufacturing enterprises in several industries either to split geographically the production capacity or to work together in supply chain organizations involving several independent entities (Perrone, 2005). These network organizations raise the need for new business models and management tools (Abid *et al.*, 2004). On the other hand ICT and market globalization offer to manufacturing enterprises the opportunity of adopting new business models. The coordinated co-working among various responsible units is the driving element of the decision making in the network enterprise.

In this context, effective operations management is the challenging task and involves distributed problem solving tasks. Specifically, in production planning the concern on internal production planning is replaced by the complexity of external supply planning since this supports the network operation. As soon as a manufacturing unit tries to achieve coordination with its partners, it quickly faces difficulties associated with different operational conventions, locally specific constraints, software legacy and properties, conflicting objectives and misaligned incentives. Even in Distributed Production System (DPS) consisting of manufacturing units belonging to the same firm coordination is a critical issue. Coordination can be easily achieved through standardization. In heterogeneous contexts standardization

1 enables the sharing of activities which belong to the same process and it is useful to manage
2 interdependencies. In order to achieve the enterprise goal, distribution need integration and
3 coordination among contributions from different entities and this requires that different systems share
4 an ontology providing a common semantics. In literature integration issues have been largely treated
5 and three levels of integration are recognized: physical, application and business integration (Chen,
6 2005). Michel (1997) considers that integration can be obtained in terms of: data, organization
7 (modelling of systems and processes) and communication. Integration can also be developed through
8 consistent enterprise-wide decision making (Doumeingts, 1998).

9 In a distributed environment decision making processes can be treated basically following two
10 approaches: a centralized one in which an unique decision-making entity, basing on a hierarchical
11 structure with a bottom up procedure, plans activities at lower levels or a decentralized one in which
12 autonomous entities, basing on an etherarchical structure, participate actively in the decision making
13 process.

14 The first approach presents well-known drawbacks (McEwan and Sackett, 2001) (Rahimifard, 2004),
15 while in order to adopt the second one Multi Agent System (MAS) tools are strictly required (Perrone
16 *et al.*, 2003).

17 Agent Based Manufacturing focuses on bridging the agent theory to manufacturing systems and can be
18 defined as a design approach that tries to describe the behaviours of distributed operations and decision
19 making units in manufacturing systems (Huang and Nof, 2000); in a physically distributed production
20 environment MAS can give a more fitting contribution. MASs reflect the distributed and autonomous
21 nature of distributed systems providing a natural way to design and implement such environments
22 (Karageorgos, 2003). MAS techniques have been largely used for their suitability in modelling
23 complex systems involving multiple autonomous agents with internal knowledge and reasoning engines
24 which communicate and negotiate with each other by exchanging messages according to specific
25 negotiation protocols.

26 The aim of this paper is to face with production planning issues in DPS and to suggest a negotiation
27 support system (NSS), based on MAS technology, to manage the related decision processes.

1
2 The paper is structured as follows: section 2 focuses on distributed production systems (DPS) and
3
4 defines a specific DPS model; production planning issues in DPS are discussed in section 3; section 4 is
5
6 dedicated to a brief overview on the negotiation process and introduces the classification scheme
7
8 adopted to design the NSS and compare it with the classical classification system proposed in scientific
9
10 literature: the negotiation support system and the related agents architecture are proposed in section 5;
11
12 section 6 draws some conclusions and indicates future research paths.
13
14

17 **2. Distributed Production Systems**

18
19
20 Market globalization has offered to companies the possibility to split geographically their production
21
22 capacity; business opportunities lead companies to work together in temporary organizations; in the
23
24 same firm, business units behave as autonomous profit centres and compete each other for the
25
26 production capacity allocation.
27
28

29
30 Three strategic options can be jointly adopted and can generate a complex variety of enterprise
31
32 organization models. In particular the first option in literature is known as multi site production system
33
34 or distributed production system; the second one is known as virtual enterprise and the third embraces
35
36 holonic manufacturing system or, in a broad sense, the divisional organization, while combinations of
37
38 them are not deeply investigated. A common problem arising in each of the considered configuration or
39
40 in configurations originated from a combination of them is the degree of autonomy that needs to be
41
42 embedded in each potentially autonomous entity.
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45
46 Members of a virtual or real enterprise need to be properly coordinated to achieve reduction in lead
47
48 times and costs, alignment of interdependent decision-making processes, and improvement in the
49
50 overall performance of each member, as well as of the entire enterprise. Distributed firms in which
51
52 each entity has a certain degree of autonomy need to reconcile all the contributions from all over the
53
54 world.
55
56

57
58 A distributed enterprise, that is an enterprise with multi site production facilities, presents some
59
60 characteristics similar to a Virtual Enterprise (VE): as a VE is made of independent functional units
behaving like a single company, in a distributed enterprise units belonging to the same enterprise

1
2 behave like autonomous units looking for local goals in the solution domain framed by a global
3
4 decision maker. This relies upon the belief that empowerment and self control in heterarchical systems
5
6 provide increase in agility and flexibility (McEwan and Sackett, 2001) meanwhile, with respect to the
7
8 hierarchical ones, they allow a drastic reduction in computational efforts to find out the right solution
9
10 (Rahimifard, 2004)
11

12
13 The distributed production system, which has been considered here, is inspired to the one of a
14
15 worldwide electronic component company, which is world leader in developing and delivering
16
17 semiconductor solutions; it is made up of geographically dispersed reconfigurable manufacturing units
18
19 (Bruccoleri *et al.*, 2003a).
20
21

22
23 Generally, companies employ geographically dispersed parallel manufacturing facilities for reasons
24
25 such as savings on transportation costs/time and /or to improve the customer service by locating the
26
27 plant closer to the customer (Kanyalkar, 2005).
28
29

30 The considered company has a divisional organization and the top management is named corporate;
31
32 each division is named group; it is in charge for a product family commercialization and it has its own
33
34 objectives. Each group can fulfill the collected orders thanks to the reconfigurable characteristics of the
35
36 manufacturing plants.
37
38

39 Reconfiguration capabilities offer clear advantages to the enterprise while increasing the complexity of
40
41 production planning activities.
42
43

44 As a result the considered company has two of the keys organizational characteristics mentioned at the
45
46 beginning of this section: it has a strong divisional structure and it has a multi site production capacity.
47
48

49 A decentralized coordination architecture and, specifically, agent based technology are strictly required
50
51 for approaching such complexity as it will be shown in the next sections.
52
53

54 55 **3. Production Planning in DPS** 56

57
58 In a multi site production set up, plants can be parallel (each producing the finished products and
59
60 supplying the market) or serial (some plants producing intermediate products supplying other plants,
which convert them in finished products). The parallel multi-plants production planning problem can

1
2 be approached in two approaches: a static one which assigns *a priori* plants to specific products (in the
3 considered case to particular groups) or a dynamic one which uses an integrated production planning
4 that assigns a plant to a product basing on the current (exogenous and endogenous) conditions. Usually
5 the choice depends on strategic decisions: in order to adopt dynamic allocation, production sites should
6 possess the technological capacity necessary to realize all the product families. In case of
7 reconfigurable manufacturing sites the dynamic approach is more suitable.

8
9 Moreover in case of production site belonging to different enterprises the integration feasibility
10 becomes a critical aspect.

11
12 As a decentralized production system aims at achieving goals deriving from localization, production
13 management policies cannot fully adopt the classic hierarchical approach. System complexity and time
14 based competition push towards *sharing* decision making processes. Production planning and control
15 approaches usually adopt different tools depending on the considered time horizon and maintain,
16 anyway, a centralized vision. Usually a manufacturing organization, after having planned long term
17 activities (strategic level, capacity planning) needs medium term plans (tactical level, aggregate
18 production planning) and short-term plans (operational level, master production schedule): these plans
19 differ in the type of information available at each stage. As discussed in (Kanyalkar and Adil, 2005),
20 there are different ways of integrating the aggregate and detailed planning problems. In the proposed
21 approach, that is conceived for a make to order environment, aggregate and detailed plans are found in
22 subsequent solutions and the higher level solution imposes constraints on the lower level models.

23
24 To summarize, the following critical aspects should be taken into consideration during production
25 planning in DPS:

- 26 – Parallel/serial and static/dynamic approach;
- 27 – Degree of autonomy of each plant ;
- 28 – Decomposition of the entire process in different levels;
- 29 – Coordination of different level variables;
- 30 – Coordination tools at each planning level.

1
2 The research here presented proposes a decision support system for production planning activities
3 structured in different levels (time horizons) according to a classical view point, providing for each step
4 the active involvement of the interested actors. This last requirement promotes decision autonomy:
5
6 autonomy becomes a key issue in achieving the dynamic dimension required in the actual market
7
8 scenario. Also, as stated above, the decision making process adopted in production planning activities
9
10 should always guarantee global satisfaction level by means of coordination and this is accomplished by
11
12 negotiation as explained in section 4. The proposed DSS is suitable both for serial/parallel and
13
14 dynamic/static approach.
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22 **3.1. PP in the considered industrial case**

23
24 In the considered example, every year, the corporate level assigns to the company groups (responsible
25 for product families such as electronic memories) a certain level of the total production capacity (called
26 capacity ownership) basing on long-term demand forecasting and products strategic positioning. Every
27 three months the groups, after having collected backlog and forecast orders coming from the regional
28 divisions, according to the ownership they hold and to the demand they have to supply, make their
29 capacity allocation plan. If the group capacity ownership is not enough to supply the demand orders,
30 then the group can negotiate portion of capacity with the other groups whose assigned ownership
31 exceeds their actual demand (Lo Nigro *et al.*, 2005). In practice, such negotiation and consequent
32 possible exchange of capacity turn out into a re-assignment of some production plants to a different
33 group. Plants assigned at the beginning of the year to the production of components belonging to a
34 specific product family, could be reconfigured throughout the year for producing different type of
35 components, i.e. different product families. Also, within the annual quarter in which the assignment of
36 plants to group remain fixed, orders of products belonging to a product family (group) must be
37 allocated to the plants temporary assigned to the group. Plants represent reconfigurable production
38 systems able to be reconfigured in the medium period (within the three months) in order to
39 manufacture different types of product of the same part family.
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Such brief description demonstrates how the production planning process in distributed organization can result complex, multi-period, multi-decision and multi-issue when a somewhat reconfigurable capability is considered. Figure 1 reports an IDEF0 view of such process in DPS made up of reconfigurable plants.

3.1.1 IDEF0 architecture. The production planning process is decomposed in 5 levels and each PP activity reported in Figure 1 is related to a different time horizon and concerns different PP levels.

The TOP PP Level (activity A1) starting from information about 1 year demand forecast and priorities for each group deriving from strategy considerations, assigns the global ownership to groups.

The output of activity A1 represents an input for A2 together with groups' priorities and demand forecast for the considered time horizon of three months. Reducing the forecast horizon, future estimates are more reliable and at the HIGH PP Level a tuning in ownership allocation is allowed.

The MEDIUM PP Level focuses on the same time horizon of the previous level but it aims at assigning each plant to a group basing on the output of level 2.

LOW level and SHOP FLOOR level concern both real time planning issues: the first one allocates, for each group, orders to one of the plants assigned to that group, while the last one is responsible, for each plant, of the allocation of jobs to resources.

Please insert Figure 1 about here

4. Negotiation support system

Negotiation is one of the most flexible coordination process in the economic field. Actually, its application fields enfold whatever human activities: working activity, entertainment activity and relational activity.

Usually, negotiation is chosen when the transaction, which needs to be coordinated, involves two or more actors with conflicting goals. The conflicting aspects refer to the possible solutions; indeed, each actor prefers a different solution, while the final agreement presents advantages for both parties respect

1
2 to their own "best alternative to a negotiated agreement" (BATNA) (Fischer and Ury, 1981). Then,
3
4 parties need each other because a strict interdependency exists in the course of actions they want to
5
6 pursue: this interdependency asks for coordination.
7

8
9 In the manufacturing context negotiation represents a powerful decision support tool. Negotiation could
10
11 be applied for internal conflicts (Sousa and Ramos, 1999, Cooper and Tabled-Bendiad, 1998) where
12
13 different enterprise functions or divisions search a trade-off accord for conflicting objectives. On the
14
15 other hand, it could also be used to regulate external transactions in the two main directions of the
16
17 supply chain: towards suppliers and towards customers. More generally, enterprises could need
18
19 negotiation to interact with different elements of their industry sector.
20
21

22
23 In particular the paper will use the classification system proposed in (Lo Nigro *et al.*, 2005) to
24
25 characterize negotiation process at each level. The proposed classification scheme allows formalizing
26
27 the negotiation process in 3 macro activities as shown in the IDEF3 notation reported in Figure 2:
28
29 "Structure Identification", "Meta Negotiation for Protocol" and "Negotiation Dynamics". Structure
30
31 identification as detailed in Figure 3 (a) analyses the problem to be solved (in this case DPP), identifies
32
33 the conflict reason, the involved actors and their roles, and the inherent sub-negotiations. The meta-
34
35 negotiation for protocol is depicted in Figure 3 (b) and consists in establishing the interaction modes
36
37 among the involved actors: the communication channel (how and what to communicate with who),
38
39 time relations among sub-negotiations and among issues conflict resolution (static dimension), rules to
40
41 manage the *dispute* (how and when a solution can be submitted, how long the process goes on) in its
42
43 evolution phase (dynamic dimension). Finally, negotiation dynamics activity, reported in Figure 3 (c),
44
45 refers to the assessment by each actor of the strategy and the tactic adopted to formulate offers and/or
46
47 to evaluate counteroffers; this requires the definition of the actors' utility functions.
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53
54 The above mentioned schema can partially fit the Montreal taxonomy for e-negotiation (Ströbel and
55
56 Weinhardt, 2003). The Montreal taxonomy aims at achieving a well structured approach for the design
57
58 of electronic negotiation and at allowing a comparison of a broad variety of e-negotiation designs and
59
60 systems. The high granularity of the proposed taxonomy, able to embrace all kind of e-negotiation
systems, is outsized for the aim of this paper that focuses on a particular business environment. On the

1
2 other hand the presented research shares the perspective assumed by Lomuscio *et al.* (2003) where the
3
4 interest is on automated negotiation among autonomous agent; this gives relevance to the negotiation
5
6 dynamic variables (strategy and tactic) and to the agent characteristics.
7

8
9 Moreover, the Montreal taxonomy is based on the Media Reference Model where media are platforms
10
11 where transactions are coordinated through agent interactions; it identifies 4 phases of interaction
12
13 limiting the attention to the intention and agreement phases neglecting the first phase (knowledge) and
14
15 the last one (settlement). Even if it declares to address the agreement phase, it doesn't cover effectively
16
17 it but, focusing just on the negotiation medium services, it limits the analysis using a static perspective.
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24 Please insert Figure 2 about here
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29 Please insert Figure 3 about here
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34 **5. Negotiation Support System for DPP**

35
36
37 This paper proposes negotiation as mechanism to be used in all of the activities presented in Figure 1
38
39 (tool to allocate ownership, tool to re-modulate ownership, etc.); negotiation is proposed as
40
41 coordination tool to resolve conflicts arising at each level of the DPP process. The actors which are
42
43 involved in the process (corporate, groups, plants, orders and jobs) have to find out an agreement, step
44
45 by step. They are not allowed to quit the process or opt for other alternative (for example is not possible
46
47 to estimate the best alternative to a negotiated agreement); then negotiation supports actors in satisfying
48
49 their own utility function by matching the best counterpart.
50
51
52

53
54 The negotiation process of each level is complex and asks for a detailed analysis partially conducted by
55
56 the authors in other works (Bruccoleri *et al.*, 2003a, Perrone *et al.*, 2003). In this paper a general
57
58 framework able to catch common aspects at different PP levels and to support a MAS implementation
59
60 is proposed.

1
2 The following items refer to the service oriented negotiation (Faratin *et al.*, 1998) based on the
3 Rubinstein protocol (Rubinstein, 1982) and on the 2-party many-issues models of Raiffa (1982). It is
4 valuable to specify some basically assumptions valid for each level:
5
6
7

- 8
9 i. the negotiation goes through the following steps: one (or more) of the actors makes an offer;
10 interested actors playing a role of potential partner respond by either accepting the offer,
11 rejecting it (through a reactive function and according to the Rubinstein Protocol) or proposing
12 a counter offer (using a creative function);
13
14
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16
17
- 18 ii. the negotiation is multilateral (it is possible to identify two roles each with a number of
19 actors greater than one);
20
21
22
- 23 iii. the negotiation is time and resource constrained.
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25
26

27 **5.1 Negotiation at different PP levels**

28
29 In this section negotiation variables, which have been located in Figure 3, are defined for each level.

30
31 It is interesting to observe that some variables are common for all the levels, in particular dynamic and
32 static variables of protocol. It is assumed that, as in the Rubinstein Protocol, actors can take actions in
33 the negotiation only at certain times in the set $T = \{0, 1, 2, \dots, 2n\}$ that are determined in advance and are
34 known to the agents; in particular buyers/sellers submit order/offers to all the sellers/buyers and at the
35 successive step sellers/buyers reply (parallel negotiations are admitted, that is each actor can negotiate
36 with more than one potential partner). Negotiation ends after n cycles (rounds) of offer/counteroffer or
37 order/counterorder (with or without agreement) or before (if any agreement is achieved). In case of
38 multi-issue negotiation, a comprehensive text approach is adopted to bargain each issue (all issues are
39 indicated contemporary in an offer/counteroffer). The comprehensive approach offers the chance to
40 compensate different issues utilities and this can be helpful if parties give to the issues different order
41 priorities.
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5.2 Agent Architecture

Actors involved in the DPP are: corporate, groups, plants, orders, jobs, resources. They have characteristics which are proper of MAS: goal-oriented, collaborative, flexible and capable of making independent decisions on when to act (Etzioni and Weld, 1995). Actually, involved agents pursue their own goals, interact with other agents to bargain a common action plan, get different roles along the process and know when and how to act in accordance with the concerted protocol.

In particular, referring to the UML notation of Figure 4, it can be observed that a generic actor has a rational component, in charge of the negotiation process, and an interface component that takes care of the relationships with other agents. Negotiation agent can behave as buyer or as seller and the interface agent manages communication channel and is in charge for updating the actors' mental state (in this case information about the current negotiation process) when information arrives, receives proposals and sends proposals to the correct counterparts. The behavior of the actor is not related to its original nature (plant, order or so on) but simply to the played role (buyer or seller) and this consideration can make easier the NSS design and implementation.

Please insert Figure 4 about here

5.2.1 TOP PP Level. At this level, the Corporate behaves as a seller while groups as buyers. In fact, Corporate behaves like the owner that splits ownership to groups basing on the priorities assessed at the strategic level and communicated to all the groups. Each group aims at maximizing its own negotiated ownership: in order to limit this trend and to achieve company goal, Corporate concedes ownership obliging groups to assure to the company a certain profit level according to their priorities. The conditions (the negotiation outputs) of the contracts signed in this phase would be used as control for groups performance at the end of the year. These considerations represent guidelines to keep in mind to set, in related future research, strategies and tactics.

Protocol variables to be set (the others are common for all the levels) concern the communication channel (*cc*): there exist a *cc* for each offer/counteroffer pair (it joins the corporate to each group) and

1
2 an informational *cc* to broadcast groups' priorities (from the corporate to all the groups). Negotiation
3
4 structure identification is detailed in Table 1.
5
6
7

8
9 Please insert table 1 about here
10

11
12 **5.2.2 HIGH PP Level.** Negotiation running at this level, already analyzed in (Bruccoleri *et al.*, 2003a)
13 cannot be considered tout court a service oriented one. On the contrary, it can be observed that resource
14 (capacity) is scarce and already allocated to groups while groups can change over ownership in the
15 current quarter to contract options for receiving it back in the future. To do this it is necessary to
16 introduce a lateral payment using an expedient: credits. Credits correspond to a virtual production
17 capacity and are equally distributed to the groups at the beginning of each year; they are used to buy
18 capacity, then group with a great amount of credits has a great power contract to obtain capacity.
19
20

21
22 At this level, basing on the quarter forecast and on the ownership assigned at the previous level, group
23 can get a buyer or a seller behavior. If the workload related to the forecasted demand is higher than the
24 group ownership the group wants to buy production capacity; in the opposite condition it is interested
25 in selling the extra capacity and receiving credits.
26
27

28
29 The process proposed in (Bruccoleri *et al.*, 2003a) can be schematized as in Figure 5. Depending on the
30 assumed role the Negotiation process (*unit of behavior* 3.1 in figure 5) is articulated in different
31 activities as Figure 6 shows for the buyer (a) and the seller (b) roles.
32
33

34
35 Seller and buyer adopt a time dependent tactic and use generative function for the order and counter
36 order formulation.
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40 Please insert Figure 5 about here
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44 Please insert Figure 6 about here
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2 At this level, there exists only the cc for the offer/counteroffer. Negotiation structure identification is
3
4 reported in table 2.
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14 **5.2.3 MEDIUM PP Level.** This level has the same time horizon of the previous one but involves
15 plants as active participants which have to be assigned to groups basing on the ownership obtained at
16 the end of the HIGH PP level. Assuming that each plant is a cost and profit center, it is interested to be
17 assigned to the most promising group in term of future profit; the plant, to avoid imperfect
18 commitment, asks a price to assure its availability. Moreover it can happen that group catches plants at
19 different round offering an increasing price but giving it a lower priority in term of guaranteed
20 workload. So plants assess a risk attitude, which is therefore used in their reactive function formulation.
21 Negotiation starts with the price submission offered by each group; each plant evaluates each offer and
22 replies by accepting it or asking for a new offer. The negotiation structure identification, for the
23 MEDIUM level is reported in table 3.
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37 Buyers (groups) adopt a generative function and a time and resource dependent tactic (Perrone *et al.*,
38 2003), while sellers adopt a reactive function and a time dependent and imitative tactic; strategy is
39 constant for both roles.
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44 At this level there exists only the cc for the offer/ counteroffer.
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49 Please insert table 3 about here
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54 **5.2.4 LOW PP Level.** This level considers a real time horizon; each group collects orders and each
55 order is assigned to one of the plants obtained at the previous level. The problem is now decomposed at
56 a lower level: here, within each group, orders aim at achieving their objectives and plant aim at being
57 workloaded. The previous levels have a common decision making structure: the global objective is the
58 company goal and the local objectives are the group goals.
59
60

1
2 At the low level the global perspective is the group perspective and the local interests concerns order
3 and plant goals.
4

5
6 As in the previous levels, the assignment will obviously consider logistic (the distance between the
7 plant and the final customer), economic (the demand elasticity of each product) and technology aspects
8 (plant/product efficiency matrix and reconfiguration costs) but, at this level, time is most of all a scarce
9 resource. Moreover, each plant doesn't know the price agreed with other plants either their priorities.
10
11 Each plant, in the previous step, has agreed with the assigned group a price and a workload priority but
12 there aren't broadcast communication channel in the protocol, because these represent confidential
13 information.
14
15

16
17 Basically, two situations can occur: orders are a scarce resource or plants are a scarce resource. In other
18 words, it can happen that workload is greater than available capacity and vice versa; but this
19 information is not known because it results dispersed among the actors. The solution to this conflict by
20 means of negotiation will depend on the presence of a "mediator". Indeed if a third part (a mediator
21 role) is present, in the first case orders behave as buyers and plants as sellers, the roles are reversed in
22 the other case. If a third part is not present it can be argued that plants behave as sellers and order as
23 buyers because of the promises deriving from previous level (price and priority).
24
25

26
27 At this level order can undertake parallel negotiation; in a Response for Quotation environment
28 customer and supplier can negotiate to fix order characteristics. Usually customers and suppliers (here
29 orders) negotiate about price, volume and due date (Argoneto *et al.*, 2004); then, negotiation between
30 order and customer and negotiation between order and plant are interrelated. In fact, order has to wait
31 plant offer to propose a counter offer to the customer to specify the volume and the due date, while
32 order has to wait customer reply about price to offer a price to plants. Negotiation structure
33 identification, for the LOW level, is reported in table 4.
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59 Please insert table 4 about here
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At this level, there exists only the *cc* for the offer/counteroffer.

1
2 Tactics and strategies for this level will be investigated in future researches.
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7 **5.2.5 SHOP FLOOR PP Level.** This last level faces with the resource/job allocation. Each order has
8
9 already been assigned to a plant in the previous level but it could be processed by one of the available
10
11 resources in that plant. In order to choice what resource for what job, the parameters involved in the
12
13 decision are resource skill in processing the job and reconfiguration time to process it (Bruccoleri *et al.*,
14
15 2003b).
16

17
18 At the shop floor level the global perspective is the plant perspective and the local interests arise from
19
20 the opposite goal pursued by jobs and resources.
21

22
23 Negotiation structure identification, for the SHOP FLOOR level, is reported in table 5. At this level,
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25 there exists only the cc for the offer/ counteroffer.
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31 Please insert table 5 about here
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33 34 **6. Conclusions**

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37
38 Production planning process in distributed organization can result complex, multi-period, multi-
39
40 decision and multi-issue when a somewhat reconfigurable capability is considered. The decision
41
42 making process adopted in production planning activities should always guarantee global satisfaction
43
44 level by means of decentralized coordination and this is can be accomplished by using MAS
45
46 technology and automatic negotiation.
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50 The paper presents a modelling methodology for designing and implementing a negotiation support
51
52 system for DPP that can be adopted in different contexts with analogous structure and that is suitable
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54 for an automated solution.
55

56
57 A reference classification has been proposed for analysing and understanding negotiation dimensions
58
59 and for assisting the designer during the conceptual design of each specific negotiation level. A
60

1
2 common framework facilitates the implementation and the usage phase in an object oriented
3
4 environment.

5
6 In related works authors have already tested successfully the decision making structure proposed for
7
8 two of the five planning levels. Future works are directed towards the assessment of a more widespread
9
10 negotiation taxonomy (in particular not referred exclusively to the service oriented model), the study of
11
12 strategies and tactics for the first and for the last level.
13
14

15 16 **Acknowledgments**

17
18 This research has been supported by the grant of the University of Palermo under the INTERLINK
19
20 project titled “Innovative Negotiation Models for Production Planning in Reconfigurable Enterprises”
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Figure 3: Negotiation variables.

Figure 4: Agent architecture.

Figure 5 High Level PP.

Figure 6: Negotiation process at high level PP for the buyer (a) and the seller (b).

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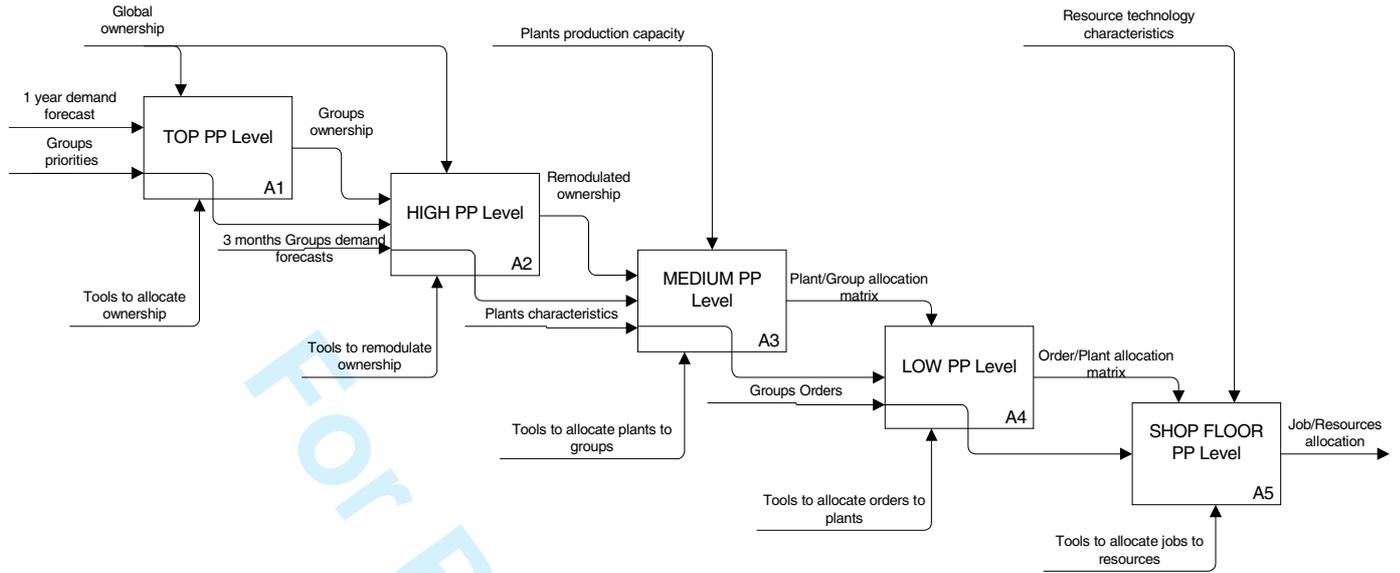


Figure 1 A layered architecture for the DPP problem.

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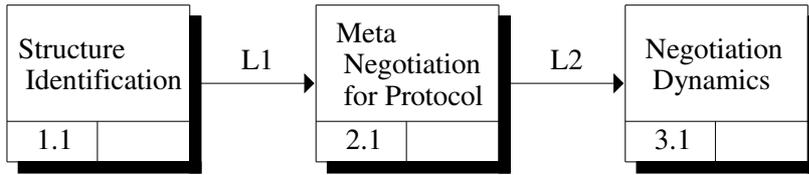
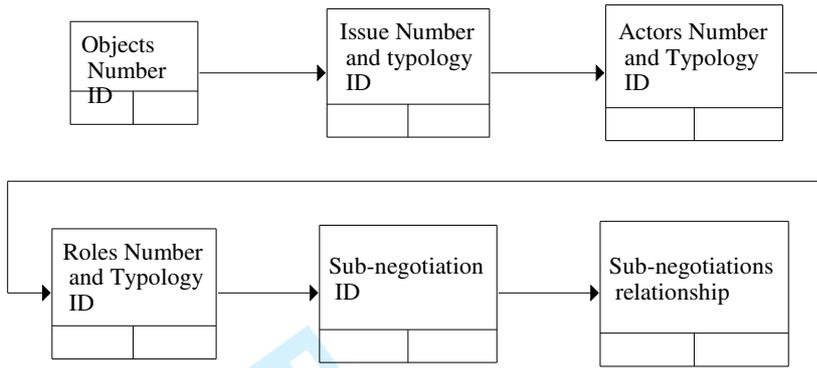
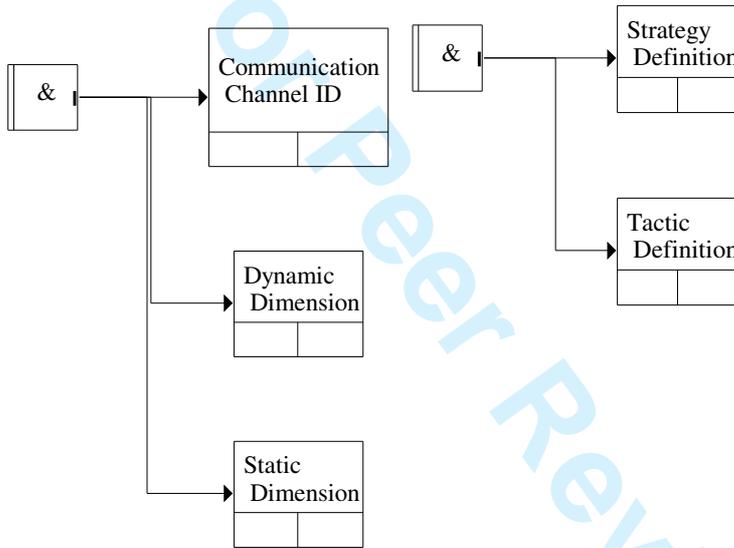


Figure 2: Negotiation design.

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(a) Structure Identification – Static Dimension Variables



(b) Meta negotiation for Protocol – Protocol Variables

(c) Negotiation Dynamics – Dynamics Variables

Figure 3: Negotiation variables.

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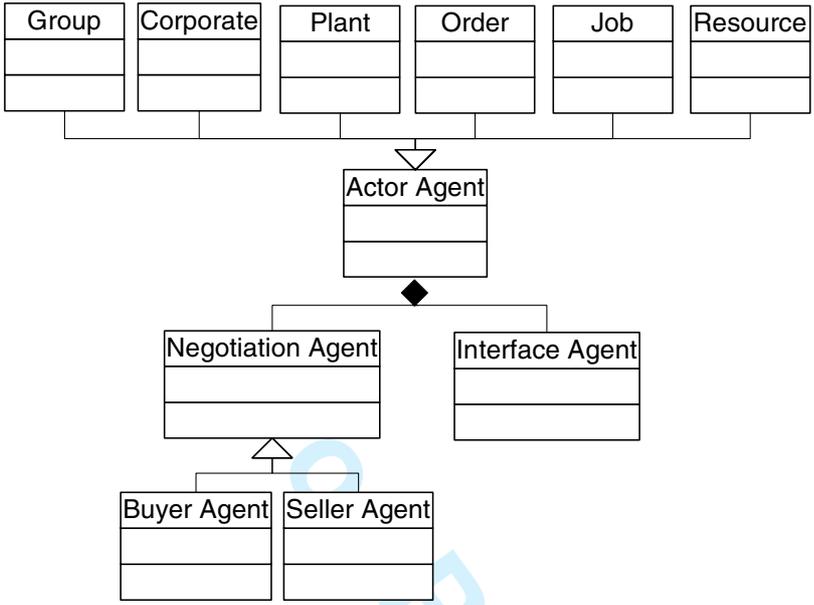


Figure 4: Agent architecture.

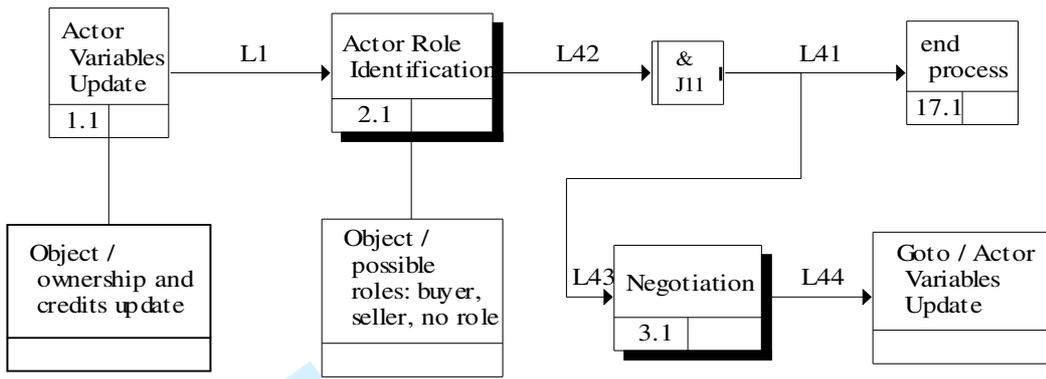
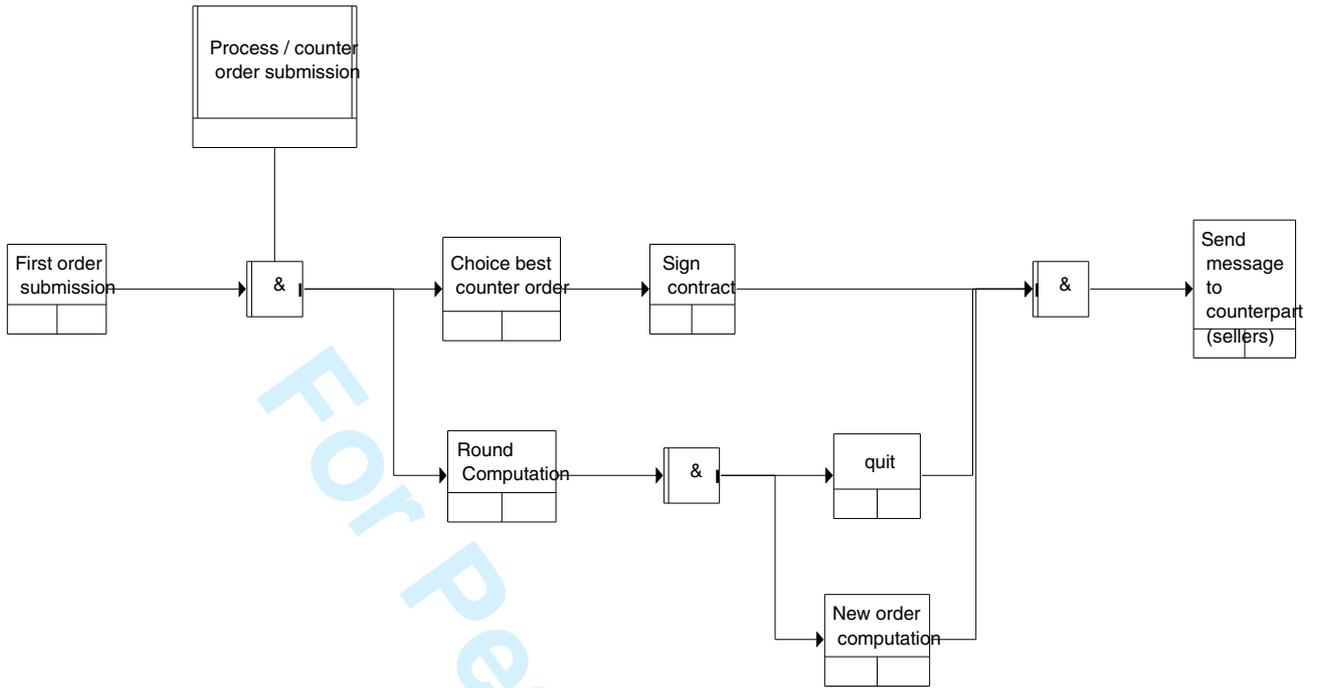


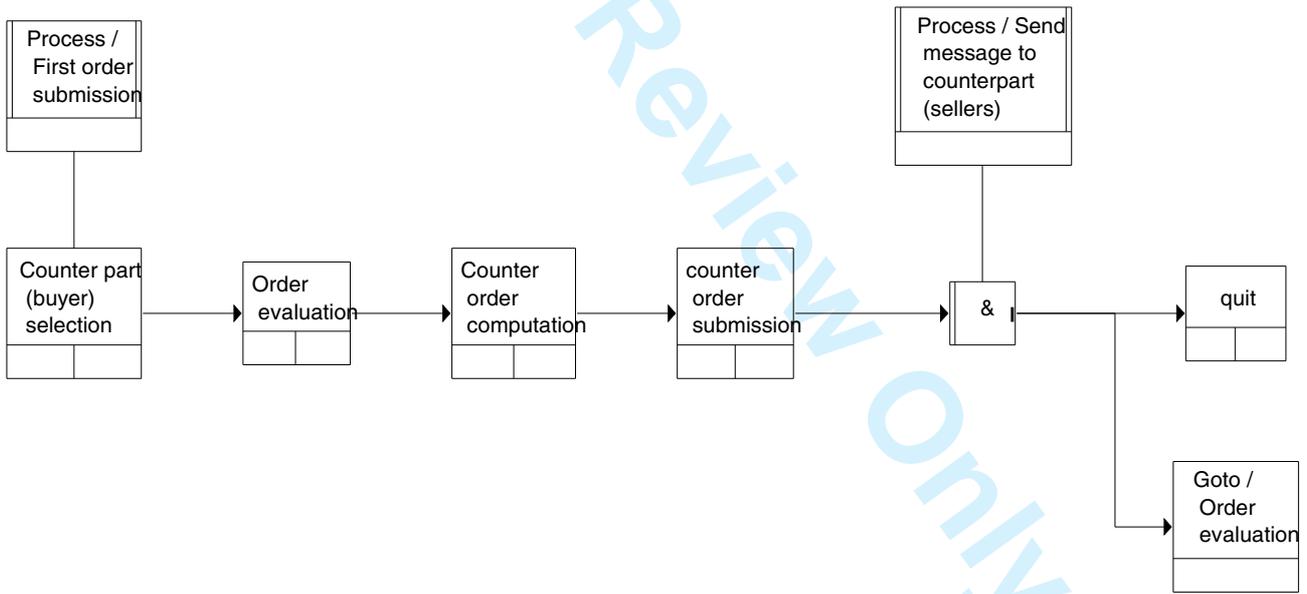
Figure 5 High Level PP.

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(a)



(b)

Figure 6: Negotiation process at high level PP for the buyer (a) and the seller (b).

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Table 1: Negotiation structure variables for the TOP PP level.

Table 2: Negotiation structure variables for the HIGH PP level.

Table 3: Negotiation structure variables for the MEDIUM PP level.

Table 4: Negotiation structure variables for the LOW PP level.

Table 5: Negotiation structure variables for the SHOP FLOOR level.

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Table 1: Negotiation structure variables for the TOP PP level.

| <i>Objects</i> | <i>Issues</i> | <i>Actors</i> | <i>Roles</i> | <i>Sub-nego</i> |
|----------------|--------------------------------|----------------------|---------------------------------------|-----------------|
| Ownership | Ownership and requested profit | Corporate and groups | Buyer (groups) and Seller (Corporate) | No |

For Peer Review Only

Table 2: Negotiation structure variables for the HIGH PP level.

| Objects | Issues | Actors | Roles | Sub nego |
|-----------|---------------------------------|--------|------------------------------------|----------|
| Ownership | Ownership and requested credits | Groups | Buyer (groups) and Seller (groups) | No |

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Table 3: Negotiation structure variables for the MEDIUM PP level.

| Objects | Issues | Actors | Roles | Sub nego |
|------------------|----------------------------|----------------|-----------------------------------|----------|
| Plant assignment | Plant assignment and price | Groups, plants | Buyer (groups) Seller (plants) | No |

For Peer Review Only

Table 4: Negotiation structure variables for the LOW PP level.

| Objects | Issues | Actors | Roles | Sub nego |
|-------------------------|----------------------------------|-------------------|-----------------------------------|----------|
| Assign orders to plants | Plant/order assignment and price | Orders and plants | Buyer (orders) Seller (plants) | Yes |

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Table 5: Negotiation structure variables for the SHOP FLOOR level.

| Objects | Issues | Actors | Roles | Sub nego |
|--------------------------|-----------------------------------|--------------------|------------------------------------|----------|
| Assign jobs to resources | Job/resource assignment and price | Jobs and resources | Buyer (jobs) Seller (resources) | No |

For Peer Review Only