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The production planning process for a network of firms in the textile-apparel industry

Alberto De Toni^{a,*}, Antonella Meneghetti^b

^aDIEGM - Dipartimento di Ingegneria Elettrica, Gestionale e Meccanica, University of Udine, Via delle Scienze, 208, Udine, Italy

^bDiEM - Dipartimento di Energetica e Macchine, University of Udine, Via delle Scienze, 208, Udine, Italy

Abstract

The paper investigates how the decision variables of the production planning process for a network of firms in the textile-apparel industry, i.e. planning period length, material availability, the link between production orders and customer orders as regards colour mix, can affect the system's time performance, whose measurement has involved the creation of two new indicators. To adhere to reality, we studied and collected actual data from one of the most important Italian companies, the Benetton Group SpA and using these observations as a basis, a simulation model was built. Only the production planning period compression has been recognised as yielding a significant improvement in the external time performance. A relation between the external time performance and the internal time performance of the network is recognised. The cash flows associated with different lengths of the production planning period are analysed. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

There is ample literature regarding investigations on time-based competition issues involving single enterprises. Based on the distinction between the external and the internal configuration of a firm, two types of time performances have been identified: the external, visible to clients, and the internal, measurable by the company but not manifest to customers [1]. The former can be related to the frequency at which new products are introduced into the market, thus measuring the innovativeness

of supply, and to delivery time, which describes the ability to quickly satisfy clients' needs. As they can positively modify the customers' perception [2,3], they have to be regarded as the source of competitive advantages in a time-based philosophy.

The paths which can be followed by an enterprise to improve its external time performances have been reduced to two alternatives [4]: a traditional approach, based on applying over-resources (personnel, inventory, etc.) and increasing costs, and an innovative one, based on sped-up processes leading to a structurally faster company without additional costs. The latter approach deals with internal time performances as the means by which the external ones are improved; shorter time-to-market and lead times in the productive-logistics phases, in fact,

*Corresponding author. Tel.: +39-0432-558330; fax +39-0432-558251.

E-mail address: detoni@uniud.it (A. De Toni)

describe an agile enterprise which can profit from its quickness [5].

Practices that lead to reducing the time needed at the product development stage have been generally related to Concurrent Engineering, as analysed by many authors [6–10]. In regard to the contraction of lead times along the operative chain, the literature has identified successful practices with the JIT core ones in the area of procurement [11,12], manufacturing [2,3,13–17] and distribution [18,19].

Very little, instead, is known about the relation between practices and time performances for new forms of organisation such as networks of firms. These systems can be placed between the two extremes represented by fully independent firms, linked only by market laws, on one hand and hierarchical enterprises on the other. Network configurations allow small and medium sized firms to better face the new challenges from world-wide competition and the great Ford age companies to achieve the flexibility and responsiveness required by a turbulent market [20,21]. Therefore, as time-based concepts are extended to networks of firms, areas for improvement and successful actions must be identified.

It has been suggested that a crucial aspect of networks is the coordination of its units, making, in fact, the system a “purposeful configuration” [22]. Therefore many authors have highlighted the role of the enterprise that manages the whole network, which has been called the hub firm [23], spider’s web [24], strategic centre [25]. We have been wondering what behaviour this main firm should undertake to transform the network into a time-based competitor.

If the focus is set on productive-logistics phases, coordination is performed by production planning. Consequently, it can be reasonably expected to represent the process by which time-based concepts are introduced into the system. Production planning, in fact, determines the rate at which materials enter the operative chain and manages their progress. Thus, it can affect the rapidity and the punctuality provided to clients and therefore the system’s ability to attract more customers and strengthen their loyalty. Our attention has so been focused on the production planning process of networks as the main area for improvements.

Since the Italian textile-apparel industry is renowned throughout the world and excellent cases are available for investigation, we decided to direct our analysis to it. On the one hand, in fact, its customers are strongly sensitive to external time performances. The fashion market could probably be considered one of the most turbulent and fickle, requiring a quick response to fashion changes whose rhythms are becoming more and more accelerated to satisfy customers’ propensity for anything modern and unusual. Therefore time-based competition has been for many years a coherent strategic orientation for this industry. On the other hand, a characteristic of the Italian industrial system is the great number of small and medium sized enterprises, that have fostered the spread of networks of firms and particularly in the textile-apparel industry the creation of successful systems like the Benetton Group.

In the following sections, the network model we developed by analysing Benetton’s production system is described and constraints to the production planning process clarified.

The actions that are supposed to lead to time performance improvement are established and then verified by simulation. Finally, the results are explained and paths leading towards time-based competition identified.

2. The system model and the production planning process

After collecting and studying actual data from Benetton’s production system, a logic model of a knitwear network was built. The main firm responsible for the strategic orientation and coordination of the network is recognised; it entrusts each phase of the production process to a certain number of firms (see Fig. 1).

The system works by successive productive campaigns, that are related to seasonal collections, with a make-to-order approach. Due to the high variability of the market and the aggressiveness of competitors, all client orders are not received before the associated campaign begins, but are continuously collected during its fulfilment. For each collection a single delivery date is established, before which

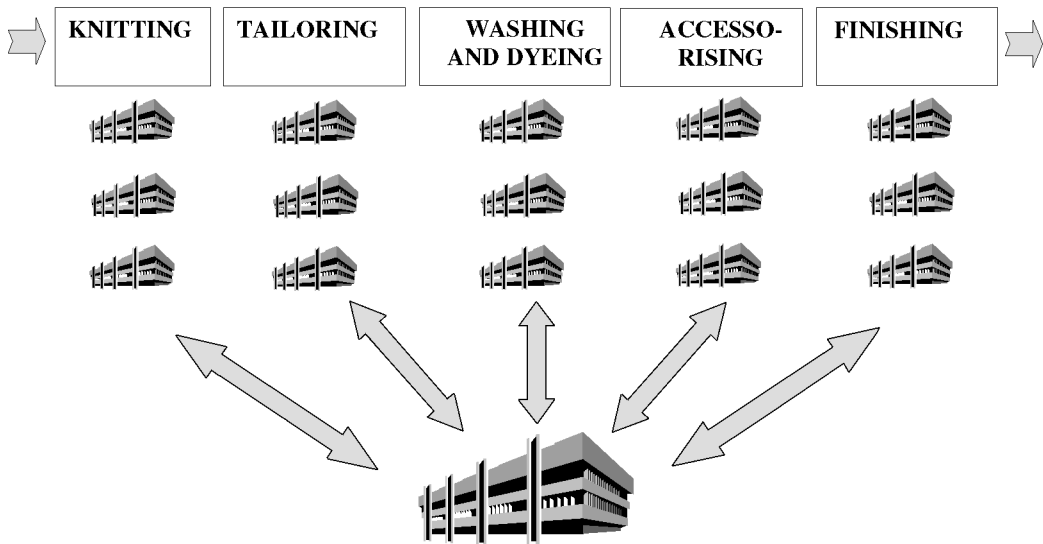


Fig. 1. The operative chain of a knitwear system.

the system promises to release products to its clients. The system is not provided with a picking area where client deliveries can be reshaped and therefore production launches are directly related to customer orders and have to comply, in particular, with the colour mix.

From a production planning point of view, the critical phase is the knitting one, where specific machines are needed depending on product characteristics, in contrast to the downstream stages where more generic machinery is required. Once products are assigned to knitting firms and processed, they can proceed in cascades along the operative chain towards successive stages. Clothes coming from the knitting phase are sewn in the tailoring stage, then washed to remove impurities and dyed if necessary; successively products are submitted to the accessorising phase, which involves embroidering, appliquéing, sewing on buttons and zips, and then to the finishing one, where they are pressed, labelled, folded and enveloped.

In comparison to what commonly occurs in manufacturing firms, in the textile-apparel system described above job size is not a pre-defined characteristic, deriving from a previous production decision, but is a short-term contextual decision.

In a single make-to-order organisation, in fact, usually a master production schedule (MPS) is computed on the basis of client orders and a previously established economic lot size, then its feasibility is checked by materials requirements planning (MRP) and capacity requirements planning (CRP) and finally in the shop floor control (SFC) jobs are assigned to available work centers and sequenced (see the left side of Fig. 2).

In a network of different firms, instead, the traditional lot size concept is replaced by one closer related to a time period rather than to a certain quantity of pieces to be processed. A production order released by the main firm is associated with the duration of the knitting capacity loading; the length of time of a production order is theoretically equal to the planning period. Due to the different production capacity of firms in the knitting phase, job size depends on the firm it is assigned to, i.e. on the number of machines available in each knitting unit of the network.

Therefore the process of production order defining makes the sequential choices of job size and job allocation to available resources time coincident (see the right side of Fig. 2). For the analysed network, scheduling becomes a short-time, simultaneous decision concerning which products

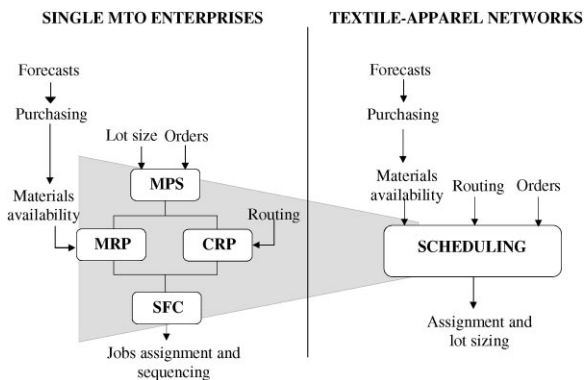


Fig. 2. The production planning process in single make-to-order enterprises and in textile-apparel networks.

to process among those already ordered by clients, to which knitting firms to assign them and what quantities to produce.

3. The production planning areas of analysis

The main objective of this study was to analyse how the production planning process could affect the network performance from a time-based point of view. Observations of the actual system indicated two important steps.

First of all, develop a rational method for generating production orders, by which the whole network could be oriented to the achievement of external time-based performances, such as respecting the promised delivery date for each collection. A computerised procedure to establish, in each planning period, which items to produce, which firms they should be assigned to and how many units to manufacture, observing the proper constraints, was not recognised in the actual system, where such decisions were personally taken by an experienced planner.

The second step involved the analysis of those variables that can affect solutions calculated by the algorithm developed in the first stage. Three factors, in our opinion, could alter production launches and very likely the time-based performance of the network:

- the length of the production planning period that influences job sizing and the timing with which products are introduced into the system;

- yarn availability, that limits quantities to be assigned to knitting firms in each planning period;
- the link between production orders and client orders regarding the colour mix, that represents a constraint when determining which products can be processed in each planning period.

The time duration of a production order, which in theory is equal to the planning period, is a crucial element in the system, as the size of jobs assigned to each unit depends on it. The queuing theory has suggested how the internal performance of lead time is related to the variability between process times due to lot size and set-ups, to the variability of arrivals at the work centre, affected by order release policies, to the traffic intensity directly influenced by the number of set-ups and by lot size, and to a scale effect associated with the average process time of each job, again affected by lot sizing [26,27]. Since in the analysed network lot size is replaced conceptually by the length of the planning period, it is reasonable to suppose that it could affect time performances. In particular, shortening the planning period and consequently increasing its frequency may allow the system greater responsiveness to client order receipts and quite likely an improved capability in assigning jobs to the network's production units. Nevertheless, increasing the number of production launches and therefore of set-ups could be expected to decrease the productivity of the knitting firms and create congestion downstream, thus prolonging the duration of the productive campaign and impeding observance of the promised delivery date.

Yarn availability, instead, represents a constraint as the colour assortment required by clients has to be respected by production launches due to the absence of a picking area where deliveries could be reshaped. As replenishment lead time is usually very long (almost two months), yarn purchase orders are mainly based on forecasts. Fashion dictated coloured materials, whose degree of customer acceptance is not known in advance, are purchased with caution and their availability is moderate in the early periods of the productive campaign, because very few client orders can be used for forecasting. If on-hand inventory were anticipated, the

capacity of assigning products to the knitwear factories, especially at the beginning of the campaign, would be enhanced, but the improvement must be compared to the risk of overstocks.

In an attempt to lighten the constraint of colour mix in the scheduling process and achieve a better performance, colour incomplete assignments could be tolerated, when needed to saturate knitting firms, by creating a small picking area where only jobs not completely conforming to client orders could wait until rejoining the coloured units that are lacking before delivery. Costs related to keeping such an inventory must be compared to the real improvement in the external time performance observed by customers.

To avoid the development of models and methods that oversimplify the complex reality they have to represent and, therefore, lead to results not truly applicable, we used the data collected from Benetton's production system. In particular we analysed the wool production division and here singled out a portion of an autumn/winter collection, composed of 149 articles, for a sales amount of 1 640 000 units, to be processed in 39 small knitwear factories. The behaviour of client order arrivals is shown in Fig. 3.

As regards the first step, the scheduling problem was faced by both linear programming and heuristics (Section 4), while in the second step the effects

of planning factors on network time performance were, instead, analysed by simulation (Section 5).

4. Production planning methods

The actual system has revealed a type of inertia in the first periods of the productive campaign. In those moments the assignment process is limited by the few client orders present in the portfolio. The availability of coloured yarn is another constraint: due to long replenishment lead times purchase orders for materials to be delivered at the beginning of the campaign are set, in fact, when customers' reaction to fashion models are not yet known and therefore they are formulated with prudence. The capacity of the knitting factories is poorly loaded in the early periods of the productive campaign. Since they are capital-intensive, this phenomenon can affect the return on investments; moreover, it becomes unfeasible to provide the network with a greater over-capacity to be used later, when the system might reach higher levels of productivity, to avoid postponing the end of the campaign. Thus, it appears that saturation of knitting firms and delivery punctuality on the part of the network to its clients are in some way related in the actual system.

The need to provide the system with a high degree of responsiveness to client order receipts and

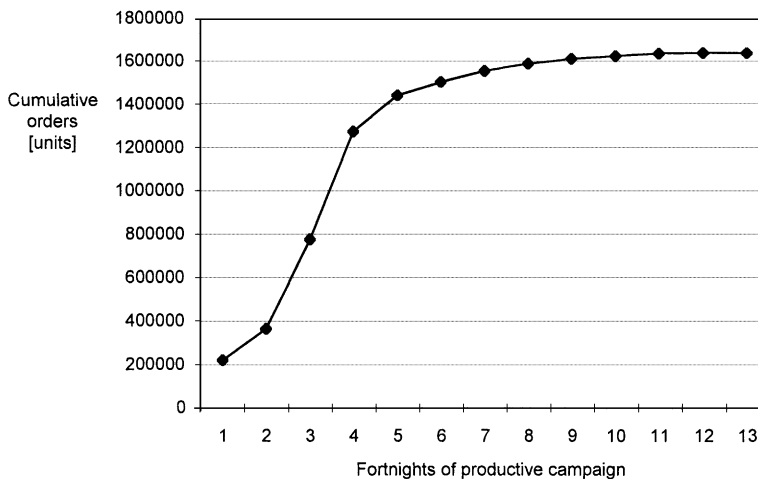


Fig. 3. Client orders arrivals during the productive campaign.

to yarn availability has suggested the adoption of a very dynamic approach to production, where the planning horizon is maintained equal to a single planning period to prevent any resistance to changes. This reflects the low predictability and turbulence of the market and can be faced only by a very flexible organisation like the network of small independent firms built by the Benetton Group.

While the production planning process of such a textile-apparel network is naturally oriented to the short term, performance has to be analysed, instead, in relation to a whole collection and the associated productive campaign. Thus the problem arose of setting the objective function for such a limited time period, while results will be evaluated over a longer horizon. We chose to maximise the capacity loading of the knitting firms, because resource saturation and network punctuality appeared to be related in some way in the actual system. Moreover it appeared as a compromise between minimising the number of articles not delivered on time and avoiding the forced assignment of models with a lower process time but very likely with a lower market value.

As regards the classification of the model on the basis of the production system typology [28], it can be regarded as a single-stage (only the first knitting phase is submitted to the planning process analysed) with parallel uniform machines, because every knitting firm can be identified with a processor characterised by a different production rate that depends on its actual capacity (number and type of machines in the firm), but not on products to be made.

The problem can be solved by integer programming as follows.

Let x_{ij} be the number of units of product j assigned to firm i , with $j = 1, \dots, J$ and $i = 1, \dots, I$. Then

$$\max \left(\sum_{i=1}^I \sum_{j=1}^J r_{ij} \alpha_{ij} \frac{x_{ij}}{p_j} \right) \quad (\text{h}) \tag{1}$$

where

- p_j is the process rate for product j (unit/h);
- r_{ij} is a large positive number that can force the production of those particular items j expressly requiring the high technology machinery pos-

essed by firm i , which can be present in the network in a limited portion due to the high investments needed;

α_{ij} is a Boolean parameter equal to 1 only if machines in firm i have proper tools to process product j (e.g. the guides needed to knit wool and rubber);

subject to:

1. Make-to-order constraint:

$$\sum_{i=1}^I \alpha_{ij} x_{ij} \leq s_j \quad (\text{unit}) \quad j = 1, \dots, J$$

where s_j is the present ordered quantity of article j ;

2. Materials availability constraint:

$$\sum_{j=1}^J \sum_{n=1}^{N_j} f_{jnkh} \sum_{i=1}^I \gamma_{jn} \cdot x_{ij} \leq d_{kh} \quad (\text{kg}) \quad \forall (k, h)$$

where f_{jnkh} is the amount of yarn k, h -coloured, needed to make a type n ($n = 1, \dots, N_j$) coloured unit of product j , γ_{jn} is the portion of product j units of colour type n and d_{kh} is the stock level of yarn k , colour h ;

3. Capacity loading constraint:

$$\sum_{j=1}^J \left[\frac{x_{ij}}{p_j} + t_{ij} y_{ij} \right] \beta_i \quad (\text{h}) \quad i = 1, \dots, I$$

where t_{ij} is the set-up time for product j to be made in firm i and y_{ij} is a boolean variable that is equal to 1 only if product j is assigned to firm i ;

4. The Boolean variable y_{ij} must be null if x_{ij} is null, i.e. if product j is not assigned to firm i :

$$y_{ij} \leq x_{ij} \quad \forall (i, j);$$

5. The Boolean variable y_{ij} must be equal to 1 if x_{ij} is not null, i.e. if product j is assigned to firm i :

$$x_{ij} \leq M_{ij} y_{ij} \quad \forall (i, j)$$

where M is a large positive number;

6. Realistic size of assignment constraint:

$$\frac{x_{ij}}{p_j} \geq a_i \cdot \beta_i y_{ij} \quad (\text{h}) \quad \forall (i, j)$$

where a_i is the minimum portion of the capacity β_i to be loaded, established for each knitting firm i .

7. Sign restriction:

$$x_{ij} \geq 0,$$

8. Integer restriction:

$$y_{ij} \text{ integer.}$$

The problem is a mixed integer programming instance and therefore is NP complete [29]; thus, solution time grows exponentially with the size of the problem ($I \cdot J$ real variables + $I \cdot J$ integer variables; for actual system data $I = 39$, $J = 149$, $I \cdot J = 5811$) towards unacceptably large values. This led us to develop heuristics, in order to obtain a more flexible and faster method for building production plans and running simulations. We were inspired by the finite loading approach [30] to create a vertical logic procedure, which assigns the best available product to each knitting firm, and an horizontal logic one, which instead tries to associate each product with the best knitting firm for making it. Both the heuristics proceed by creating for each firm or each article a set of possible assignment alternatives and by shortening this set on the basis of several criteria applied in sequence, such as ensured capacity occupation, set-up time and required machine characteristics, until a single cardinality is reached. Flow diagrams of the vertical and horizontal logic procedures are shown in Figs. 4 and 5, respectively.

The procedures were compared with the mixed integer programming model coded by Cplex; the vertical heuristic was found to behave better than the horizontal one, with an average error relative to the optimal solution given by the mixed integer programming model equal to 4.4% and 10% respectively. Both the greedy procedures showed an extremely improved resolution time due to an $O(n \log n)$ computational complexity, particularly relevant as the size of the problem increased during the analysis. Hence, the production plan for each period, i.e. the input for simulation runs, was built by using the vertical logic procedure.

5. Analysis of production planning variables

To study how production planning period length, yarn availability and colour assortment can

modify the time-related performance of the system and consequently, from a time-based competition point of view, enhance its ability to satisfy customers' needs, simulation experiments were carried out [31].

5.1. Simulation model development

To build a simulation model that is more adherent to reality, we used the actual data collected and opinions and suggestions offered by Benetton personnel.

The simulation model was built using the Simple ++ software package, which is object oriented and consequently has a greater capacity to represent complex systems with various hierarchical levels. It was, in fact, possible to assume a top-down approach to establish the main links between each phase along the supply chain and then detail each component, avoiding possible distortions of interactions at the upper levels.

In each period, jobs enter the system as planned by the vertical heuristic. After being knitted in one of the 39 small factories, when the right quantity of items is reached, they are loaded into trucks and then moved on to the next phase in the operative chain. The transport times through the network are set according to the average values recorded in the actual system.

The assignment of each job to the proper firm in the tailoring, accessorising and finishing stages is performed by choosing the least loaded factory.

As happens in the actual system, the washing and dyeing phase, considered to be a core competence of the main enterprise, is centralised. Here machines are loaded to the permitted weight merging items of different jobs on the basis of yarn type and colour. Attention is paid to the rotation of dark and light colours in dyeing machines to reduce set-up times.

To maintain productivity aligned with the observed values, breakdowns have been introduced into every shop.

5.2. Experimental design

A whole seven-month production campaign was simulated. Experiments were based on a 2^3

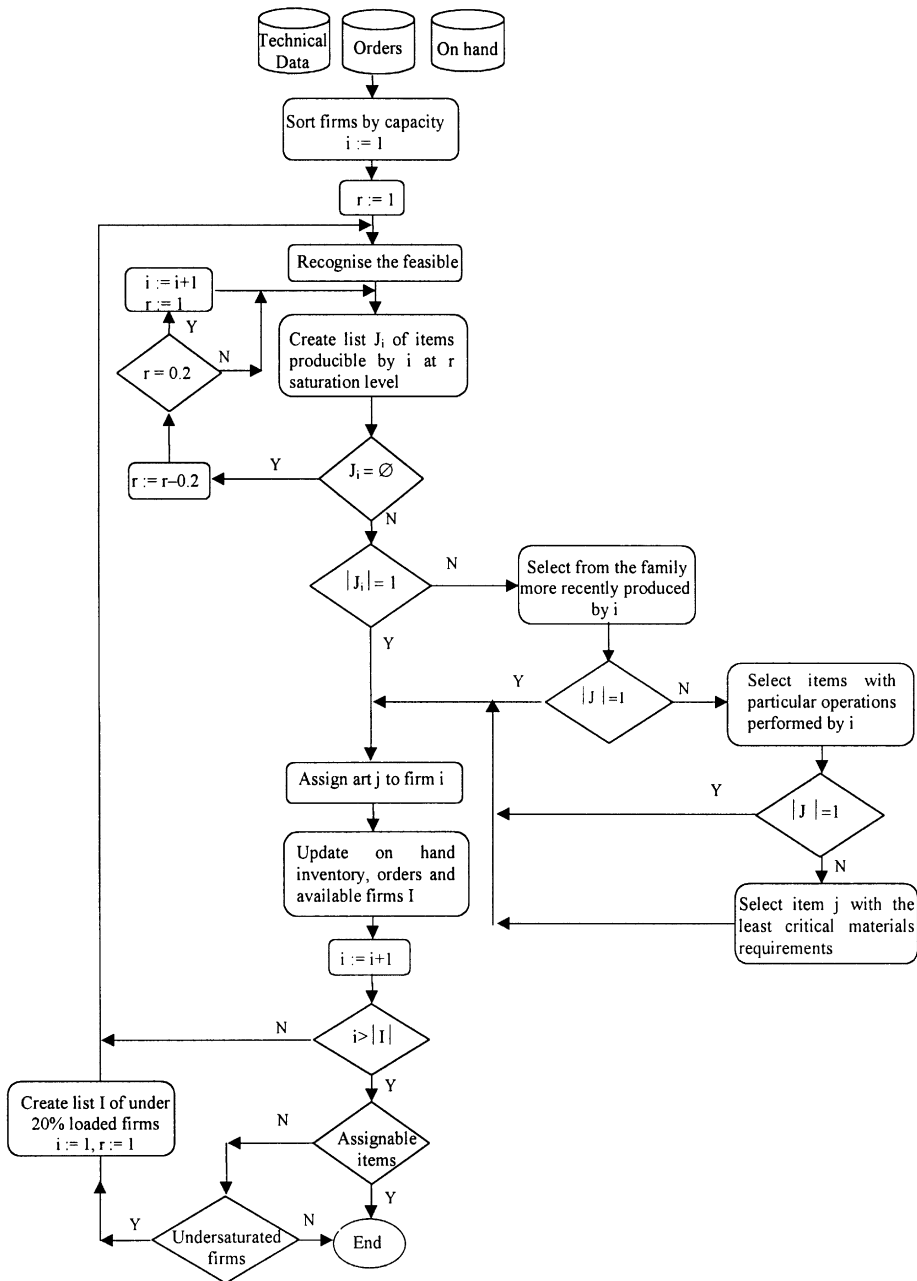


Fig. 4. Flow diagram of the vertical logic heuristic.

factorial design, where each of the three production planning variables described above was studied at two different levels (see Table 1).

The length of the planning period was set equal to respectively 3 weeks and 1 week.

As regards materials, in the actual system yarn purchase orders are set mainly on the basis of forecasts and spaced out along the campaign to meet requirements. Thus, to enhance the capacity of assigning products to the knitwear factories

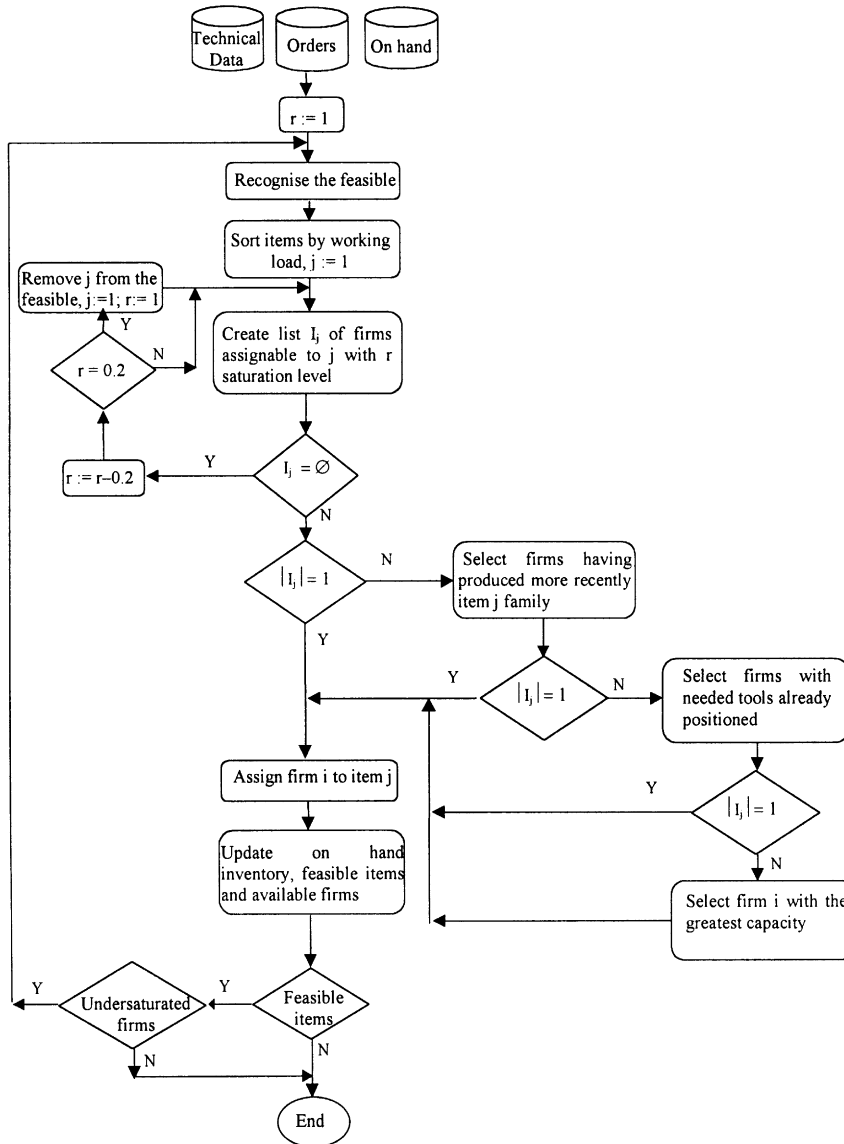


Fig. 5. Flow diagram of the horizontal logic heuristic.

especially at the beginning of the campaign, we tried to anticipate on-hand inventory, by increasing the coefficient used to space out purchase orders, equal to the portion of forecast requirements that has to be provided in each period. So we studied the behaviour of the simulated system with values of purchasing coefficients equal to those used by the actual system and those with a 50% increase. For

example, for a material whose purchase order quantity was normally set at 10% of the entire forecasted requirements, a purchase order quantity of 15% of forecasted requirements was considered as the second level.

Concerning the link between colour mix of jobs and client orders, we analysed the two situations where this relation is maintained or partially

Table 1
Factors and relative levels considered in the 2³ factorial design of simulation experiments

Factors	1st level	2nd level
Production planning period	3 weeks	1 week
Materials availability	Normal	+ 50% purch. coeff.
Colour link	Present	Partially removed

removed. We allowed, in fact, the heuristic to generate colour-incomplete production orders when needed to saturate factories, providing the simulation model with an area where jobs could wait until rejoining the lacking coloured units before leaving the system.

5.3. The response variable

Since in the textile-apparel industry production is fulfilled by successive campaigns, performances have to be evaluated in relation to the whole collection; consequently, global measures are required. For each collection, the analysed network presents a single date promised to all its clients, before which it commits itself to carry out all the orders received. Delivery punctuality is particularly important for network customers, who are retailers, since it affects their ability to fill their shelves with new products on time with fashion changes and therefore capture fickle and fickle consumers.

As an appropriate measure to evaluate system time performances appreciable by clients with regard to a whole collection we propose the *weighted average delivery anticipation* (DA), which we have defined as follows:

$$DA = \frac{\sum_{i=1}^N Q_i A_i}{\sum_{i=1}^N Q_i} \tag{2}$$

where Q_i is the number of units of the i -th job, with N the total number of jobs processed by the system and A_i is the anticipation of the i -th job, defined as the elapsed period (days) between the promised delivery date and the moment each job exits the system and products can be sent to clients (see Fig. 6).

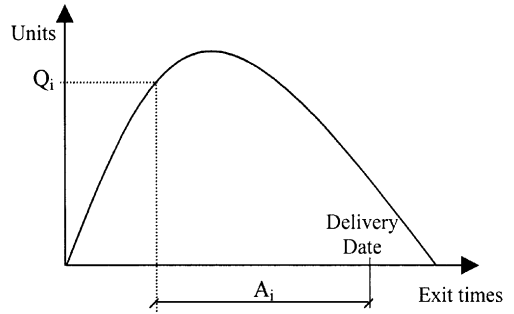


Fig. 6. Anticipation A_i of the i th job composed by Q_i units.

DA provides an estimate of the system capacity to anticipate product realisation, i.e. to react quickly to sales orders that accumulate during the productive campaign. If DA were improved, the productive campaign could start later, when the demand is better known, assuring clients the same punctuality. In this way, the yarn purchasing process would be more easily managed and consequently left-over stocks reduced. Conversely, the promised date could be brought nearer to the beginning of production, without deteriorating the capacity of the system to deliver on time. Such an action would be convenient if the system wanted to accelerate the frequency of introducing new products into the market by launching more collections in fast succession during the same season, as happens in the “flash collection” phenomena. The capability of sequencing productive campaigns without overlapping them, thanks to an improved DA, would lead to more linear processes and easier coordination between network units.

6. Simulation results

The main effects of the three factors, defined as the difference between the average response of the system when a factor moves from its 1st to its 2nd level, are shown in Table 2.

Only the length of the production planning period strongly affects time performance achieved by the system and measured by the delivery anticipation.

Therefore, only the action of shortening the production planning period can significantly influence

Table 2
Main effects on delivery anticipation of the three analysed factors

Factors	Main effects on delivery anticipation DA (d)
Production planning period length	14.052
Materials availability	0.564
Colours assortment link	1.024

the external time-based performance of the network and must be considered by management. So the availability of materials and colour link were no longer investigated, but analysis was directed at the effect of changing the production planning period.

By compressing the production planning period from 3 to 1 week, we can see how the asymmetry of the curves, which interpolate products exits from the system during the production campaign, is positively modified (see Fig. 7); consequently the weighted average delivery anticipation DA is increased.

The planning period affects the internal time performance, recognisable only by the system itself and not by its clients, along two directions.

As its length is decreased, the average lead time is reduced (see Table 3), because of a shorter job processing time; this is due to a smaller job size, which derives, in fact, from the attempt to fill the knitwear factories to capacity during a shorter planning period.

The contraction of lead times is not proportional to the related reduction in the planning period, because as job size is decreased a higher number of jobs is generated during a campaign, leading to increased set-up (see Table 4) and queue times, which counteract advantages arising from shorter processing times.

The reduction in the planning period also enhances the ability to assign jobs to the knitting firms especially in the early periods of the productive campaign, when the constraints related to availability of materials and customers' orders strongly condition the planning process.

The reaction to customers' orders is better with a shorter planning period but the number of set-ups is increased and consequently the set-up time, the

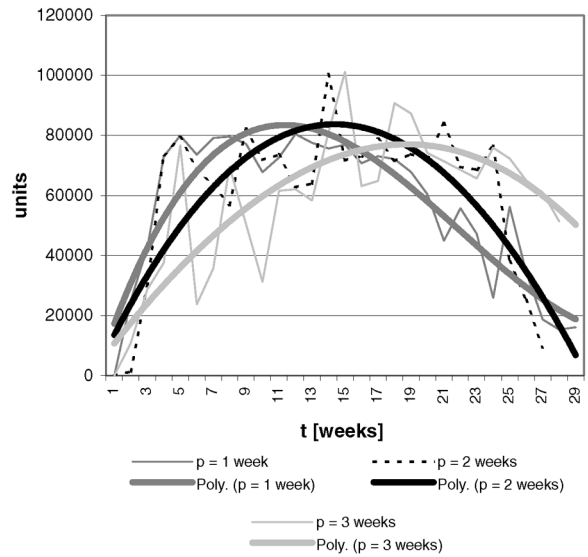


Fig. 7. Products exits from the system during the production campaign; actual data and polynomial interpolation.

Table 3
Average lead times and Work-In-Process in relation to different production planning period lengths

Production planning period length (weeks)	Average job lead time (days)	Average WIP (units)
3	27.08	334865
2	22.13	248629
1	15.19	169144

effect becoming more evident as the campaign advances and the constraints become less intense. In Fig. 8 average saturation of the knitting firms during the productive campaign is showed. Observing the interpolation curves, it can be seen how a compression of the planning period modifies their asymmetry, moving their median towards the beginning of the campaign. Thus, a 1 week planning period leads to a higher level of saturation in the first production periods, but to a longer duration of the campaign due to increasing set-ups.

These effects can be summarised by the *weighted average anticipation of saturation* (SA), that we have defined as follows:

$$SA = \frac{\sum_{i=1}^N O_i A_i}{\sum_{i=1}^N O_i} \tag{3}$$

Table 4
Jobs characteristics and total set-up times during a campaign due to different production planning period length

Prod. planning period length (weeks)	Number of jobs	Average job size (units)	Reduction percentage	Total set-up time (hours)	Growth percentage
3	453	3621	—	19 817	—
2	580	2828	– 21.90%	23 192	+ 17.03%
1	1050	1562	– 56.86%	25 197	+ 27.15%

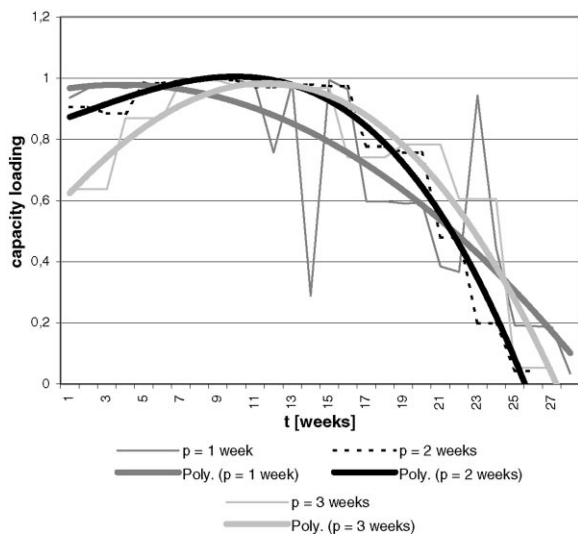


Fig. 8. Average saturation of the knitting firms during the production campaign; actual data and polynomial interpolation.

where O_i is the actual knitting hours assigned in the i th planning period, N the total number of planning periods and A_i the anticipation of the i th period, defined as the period (days) elapsed between the promised delivery date and the moment jobs of each period enter the system (see Fig. 9).

The increase in the average anticipation of saturation could provide the firms of the system with a greater chance of loading their available capacity by offering it to other subjects not belonging to the network, during the periods of structural decline of the campaign. If the asymmetry of the saturation curve were modified so that only two consecutive periods of high and low saturation levels were recognised, each production unit could rely, in fact, on an uninterrupted time interval with sufficient

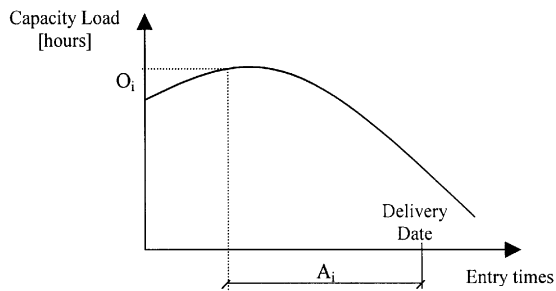


Fig. 9. Anticipation A_i of the i th period of capacity loading.

resources to be dedicated to other significant commitments. On the other hand, if the network were used to launch flash collections, i.e. mini collections added to the usual winter and summer ones to improve the frequency of introducing new products to the market, then a greater anticipation of saturation could allow the campaigns to be sequenced instead of overlapped, reducing the complexity of the production system.

Table 5 shows the external time performance, measured by DA, and the internal ones, represented by the average lead time LT and SA gained in the simulated system, when a delivery date is set at the 168th day from the beginning of the campaign. Moving from a 3 to a 1 week planning period, the delivery anticipation is improved by 22%, lead time is reduced by 44%, while the anticipation of saturation is shortened by 1.5%.

The ratio SA/LT summarises in a single indicator the effects of the planning period length on the internal time performance measures LT and SA. As can be seen from Fig. 10, the increase in the ratio SA/LT is associated with an increase in the value of the external performance measure DA. This is reasonable, if we consider that the delivery

Table 5
Internal and external time performance measures

Time performance measures	3 week prod. planning period	2 week prod. planning period	1 week prod. planning period
Delivery Anticipation (DA) (days)	72.69	84.78	88.61
Anticipation of Saturation (SA) (days)	106.26	110.19	104.69
Lead Time (LT) (days)	27.08	22.13	15.19
DA/LT	2.68	3.83	5.83
SA/LT	3.92	4.98	6.89

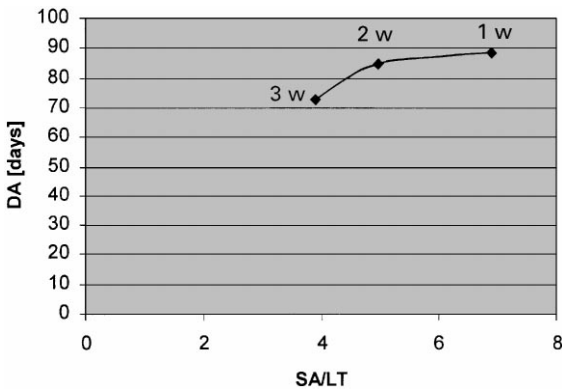


Fig. 10. Relation between the internal time performance measured by the ratio SA/LT and the external one measured by the average delivery anticipation DA.

anticipation depends on the planner’s ability to lead the system to saturation as soon as possible, so that products are introduced into the system and processed early. With the same anticipation of saturation, however, products exit from the system as fast as their lead time is shortened.

7. Time performance of the network and cash flows

A system that provides a quick response to customers’ needs can not only attract more clients and encourage brand loyalty, increasing its market share, but also win a price premium for the speed and punctuality of its deliveries.

A client that is very sensitive to time performance, in fact, might be inclined to pay a price that is a nondecreasing function of the delivery anticipa-

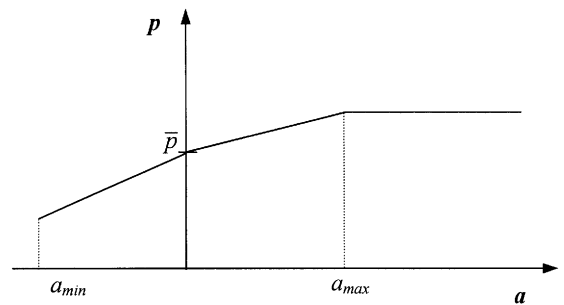


Fig. 11. Price behaviour as a function of delivery anticipation.

tion with which products are provided. On the other hand, the same client could reasonably decline paying the full price if products are not delivered on time (see Fig. 11). The following behaviour of the unit price p can be considered:

$$\bar{p}(1 + m_1), \quad a \geq a_{max},$$

$$p = \bar{p} + m_1 \frac{\bar{p}}{a_{max}} a, \quad 0 \leq a < a_{max},$$

$$\bar{p} + m_2 \frac{\bar{p}}{|a_{min}|} a, \quad a < 0,$$

where

- a is the delivery anticipation of the unit;
- a_{max} the greatest value of anticipation recognisable by clients for a price premium;
- a_{min} the (negative) anticipation for which products have still a market value;
- \bar{p} the full price set for products delivered on the promised date;
- m_1 the relative increase in the full price \bar{p} for an anticipation equal to a_{max} ;
- m_2 the relative decrease in the full price \bar{p} for an anticipation equal to a_{min} .

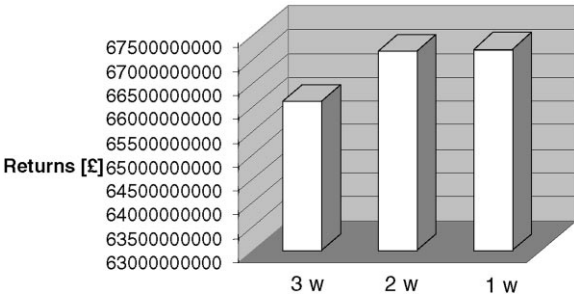


Fig. 12. Cash inflows for a planning period of 3, 2 and 1 week's length.

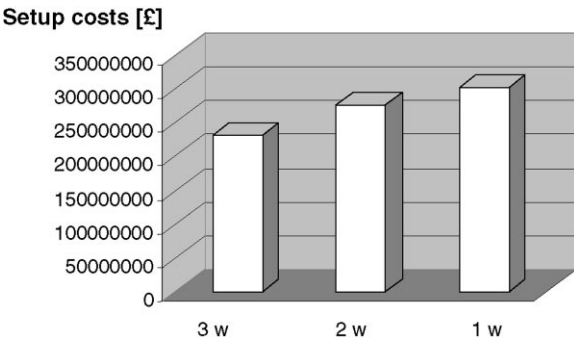


Fig. 13. Set-up costs for a 3, 2 and 1 week planning period length.

Cash inflows gained by applying the above price relation to products managed with a planning period of 3, 2 and 1 week are shown in Fig. 12, setting $\bar{p} = 35000$ Italian Lire (18 Euro), $a_{max} = 72$ days, $a_{min} = 120$ days, $m_1 = 0.2$, $m_2 = 0.5$.

Shortening the planning period length leads to increased cash inflows, but a growth in cash outflows has also to be considered. This results from more numerous set-ups and transports inside the network due to the greater number of jobs generated; Figs. 13 and 14 show their behaviour based on data from the Benetton system.

As the external time improvement gained by modifying the production planning period can increase both cash inflows and outflows, its entity must be established so that advantages can be maximised. Curves describing the behaviour of inflows and outflows as a function of external time performance have to be plotted, so that the

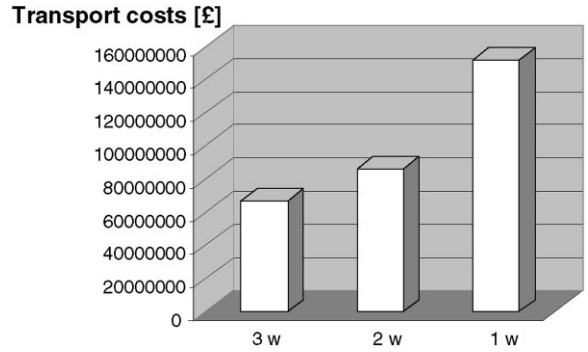


Fig. 14. Transport costs for a 3, 2 and 1 week planning period length.

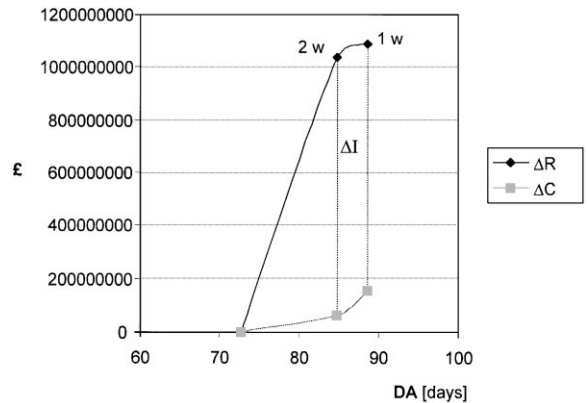


Fig. 15. Relative increase in returns (ΔR) and costs (ΔC) when moving from a 3 to a 2 and 1 week planning period.

network could choose the service level which best realises a compromise between customer satisfaction and profit.

For the analysed network, the relative increase in returns ΔR and costs ΔC by moving from an initial 3 week period to 2 and 1 week is shown in Fig. 15, where the advantages of reducing the planning period length are evident. Fig. 16 represents the increase in income ΔI associated with a 2 and 1 week reduction and the associated improvement in delivery anticipation ΔDA . The ratio $\Delta I / \Delta DA$ describes the increase in income (relative to the initial condition) which can be gained for each unit improvement in the external time performance appreciable by clients; it is graphically represented by the tangent of angles α and β identifying the possible

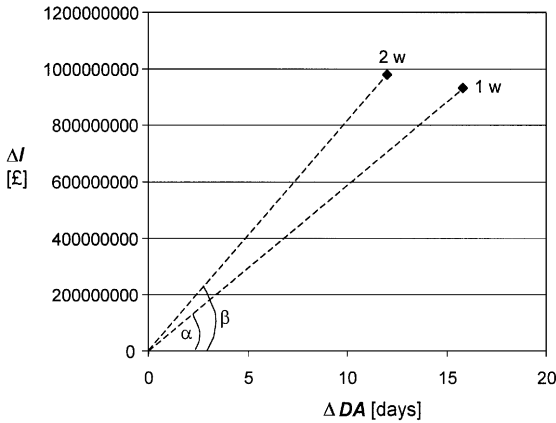


Fig. 16. Relative income increase when moving from a 3 to a 2 and 1 week planning period.

reduction in the production planning period. Thus, for the analysed network and the given data, the ratio is more favourable for a movement from a 3 to a 2 week planning period rather than a more drastic change.

8. Conclusions

Simulations show how even from a systemic as well as from a single firm point of view, achieving a favourable internal time performance is a means of gaining an external time performance, recognisable by customers.

The production planning process was found to be an important area of improvement for a network in a time-based logic; shortening the production planning period, in fact, significantly affects the weighted average delivery anticipation. It leads, however, to increase set-up and transportation costs due to the greater number of jobs generated during a campaign.

The path of the network towards time-based competition consequently appears traditional, where an improved customer service level, measured by DA, is accompanied by higher costs (see Fig. 17): the network is moved from point A to point B along its costs–service curve.

A new capability for managing the costs–performance trade-off could be reached by shifting the competition towards more advanced frontiers than

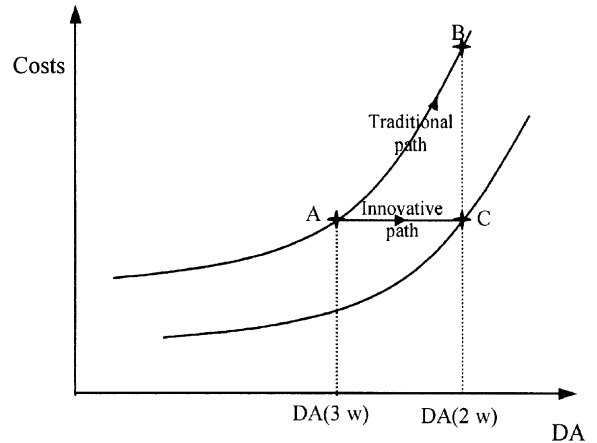


Fig. 17. Traditional and innovative path of the network towards time-based competition.

its competitors’ curves. In this way the network would be moved from point A to point C through an innovative path, where the advantage of better delivery anticipation is gained without increasing costs.

To obtain such a result, the planning period compression must be matched with system process reengineering: actions which are able to modify the technological means and managerial techniques of each firm in the network have to be undertaken so that the whole system becomes intrinsically faster as the time-based competition philosophy suggests. For example, if a reduction in set-up time were gained at each step in the chain, a greater number of jobs during a single campaign would not lead to higher costs. The behaviour described in Figs. 15 and 16 could be changed in favour of a more drastic contraction of the planning period length, so that the customer’s sensitiveness to external time performance could be fully exploited.

Thus, while the production planning process is shown to be an important area for improvement in a time-based logic, its results can be amplified by involving the other processes performed in the network.

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