MANUFACTURING REDESIGN IN THE TEXTILE INDUSTRY

Antonio C. Caputo
Faculty of Engineering, University of L'Aquila, 67040 Monteluco di Roio (AQ), Italy
caputo@ing.univaq.it

Mario Palumbo
Faculty of Engineering, University of L'Aquila, 67040 Monteluco di Roio (AQ), Italy
palumbo@ing.univaq.it

Abstract. *Present scenario in the textile and clothing industries shows a double essence in developed and developing countries: in the former high-tech, automated and informatized processes are involved, in the latter, low-tech and labor-intensive operations take place. In the perspective of Quick Response, a partial re-insourcing of manufacturing activities in high performance textile industries may involve many advantages, going from the firm's responsiveness enhancement, to higher quality level obtainable, to the possibility of satisfying customized requests on low volumes productions. In this work, after a short description of the world market in the textile sector, a proposal of re-insourcing of jeans manufacturing in a large enterprise is proposed. At first, an analysis of jeans manufacturing is carried out. Subsequently, a high production shop is proposed and dimensioned for the quick response requirements of the company. Finally, an economic evaluation has been carried in order to evaluate also the profitability of the re-insourcing operation.*

Keywords*. Textile Industry, Manufacturing Redesign, Quick Response, Manufacturing re-insourcing, TMC*

1. Introduction

According to the conceptualization developed by the Russian economist Nikolai Kondratieff, world economy evolves following periodic *waves* (the *K-waves*, after his name) marked by periods of relatively rapid expansion, followed by sluggish growth or even stagnation (Loo, 2002). The evolution of the capitalist system requires the periodical development of new high tech industries in new geographical area in order to overcome stagnation problems (Hall, 1995). In this scenario, the textile and clothing industry was born in England during Industrial Revolution, representing the high tech industry at 18th Century end. Following Hall's (1995) terminology, the global economy is currently in the *Fifth K-wave*, so the old innovative textile industry had to face four successive long periods made of booms and recessions adapting itself to the changing environments.

A commonly accepted theory explaining the evolution of global capitalist economy is the New International Division of Labor (NIDL). According to this theory, factories are periodically transferred from one geographical site to another as industrialists continuously search for areas in which lower wages apply. Textile and clothing industries, given their labor-intensive nature, follow this theory (Christerson & Appelbaum, 1995), and it can be seen a global shift of the world's textile and clothing industries towards the less developed economies, including Mainland China, Thailand, Indonesia and the Caribbean states (Bonacich et al., 1994; Dickerson, 1999)

According to the classification of the exporters countries of textile and clothing industries (W.T.O., 2000, World Bank, 2000), at second and third place for textiles exportations two developed countries can be found (Germany, 8.0% and Italy 8.0%, after China, 8,8%); moreover, as many as 10 out of the top 15 exporters are high-income economies and they altogether account for over half (52.2%) of the world's textile exports, while low-income countries, in contrast, take up 11.9%. As far as clothing industries are concerned, China results the first exporter, with 16.2%, but Italy (with 7.1%) and United States (with 4.4%) closely follow, ranking the second and respectively the fourth place. Among the 15 leading clothing exporters, eight are high-income economies and they altogether accounted for over one-third (36.8%) of the world's clothing exports. In comparison, low-income countries only contributed 20.1%.

This circumstance is apparently very strange, as clothing industry is highly labor intensive: though most textile and clothing industries seem to have been relocated to the developing countries of low wages, developed countries actually remain the most important exporters of these products. Another aspect has to be taken into account in order to explain this situation: textile and clothing industries are low-tech and labor-intensive and often represent the most important harbinger industries opening the door of export-oriented industrialization in the less-developed countries. In modern production context, however, automation and information technology is increasingly taking place in many production stages (Hoffman,1985; Hoffman & Rush, 1988; Stylio, 1996). Therefore, in the developed countries, extremely dynamic and innovative textile and clothing firms employing the latest technologies and well-paid professionals have emerged (Appelbaum & Gereffi, 1994; Knox & Agnew, 1998; Porter, 1990; Sengenberger & Pyke, 1992) and concentrated in distinct areas.

These contemporary developments highlight a double essence in textile and clothing industries: a first one, low-tech and labor-intensive, and a second one, high-tech, automated and informatized. In this double nature there is therefore a co-existence of well-paid professionals and advanced technologies in certain regions (in developed countries) and low-skill, low-paid labor force in other regions (in developing countries). The NIDL theory alone can not explain this duality in production locations and labor working conditions: flexible production theory helps to account for it, together with the continual significance of developed countries industries in textile and clothing sector.

2. Textile manufacturing industry in developed countries

Modern markets, characterized by high variability in quantity and quality of products, ask for new architectures of production systems. Rigid production, typical of the Ford era, is today out of date because of its structural reliance on large-scale internal economies of scale and mass consumption patterns. Flexible production, instead, allows for easy changes in the quantity and quality of a product and can quickly respond to shifting market situations with just-in-time delivery. Production stages are no longer carried out in one large vertically-integrated factory (typical of Fordist production system) and as a result, the scale and location of different stages may adjust flexibly in response to variations both at the supply and demand side.

New forms of industrial space called *Flexible Production Regions* (FPRs) have emerged in this scenario, characterized by networks of innovative and dynamic small firms in the same industrial sectors. *Third Italy* (Emilia-Romagna, Toscana, Marche and Abruzzo regions) and the *Silicon Valley* are FPRs examples. A major group of these FPRs do not specialize in high-technology industries typical of the Fifth K-wave but, on the contrary, on the traditional design-and labor-intensive industries, which their regional economies were based on, particularly the textile and clothing industries. A new element is the application of flexible computer-based technologies, such as CAD-CAM, which make the processes highly information-intensive, encompassing design, retailing, marketing and logistics.

The objective in the use of such technologies is to obtain a *lean manufacturing*, i.e. "a manufacturing system with extraordinary capability to meet the rapidly changing needs of the marketplace; a system that can shift rapidly amongst product models or between product lines, ideally in real-time response to customer demands" (Youssef, 1994), in the perspective of *Quick Response* (Azuma, 2001; Hunter, 1994; Perry et al., 1999; Corti et al., 2002, Bolisiani & Scarso, 1996; Scarso, 1997), i.e. "an apparel industry initiative intended to cut manufacturing and distribution lead times through a variety of means, including information technology such as electronic data interchange, point of sale scanners, and bar coding, logistics improvements such as automated warehousing and increased use of air freight, and improved manufacturing methods, ranging from laser fabric cutting to reorganisation of the sewing process into modular sewing cells" (Fisher et al., 1996). Hence, Quick Response refers fundamentally to speed-to-market of products which move rapidly through the production and delivery cycle, from raw materials and component suppliers, to manufacturer, to retailer and finally to end consumers.

In contrast to the described situation taking place in developed countries, the actual assembly and low value-added activities take place in many less-developed countries. The main activities consist of simple dyeing and sewing of garments in large volume based on instructions given in contracts from large firms. These low value-added activities do not require particular skills and are paid at piece rates or on a daily basis.

In the perspective of quick response, the resort to these activities from third parties may represent in some cases a problem, especially when high quality standards have to be met and the supplier is located at great distance and, therefore, hardly subject to inspections. In this case, it can be interesting an evaluation on the feasibility of re-insourcing the third party operations. A partial re-insourcing of manufacturing activities in high performance quick response textile industries involves, in fact, many advantages:

- providing the firm with a capacity buffer in order to respond in a proper manner to unexpected peaks in the demand and unforeseen variations of supplier lead time, thus improving the system's responsiveness;
- applying a stricter quality control to high value products;
- possibility of setting up a line for small sized pilot production runs for new products development as well as to satisfy customized requests.

All these factors indeed contribute to the quick responsiveness of the manufacturing system, because enable the firm to gain control of quick-reaction resources required to gain competitiveness in this peculiar environment.

In the following, a case study concerning the re-insourcing of some manufacturing phases of blue-jeans is illustrated.

3. Manufacturing redesign in the textile industry: a case study

A manufacturing redesign process has been carried out in a firm producing young apparel lines on behalf of third parties, namely big fashion names such as Versace, Dolce & Gabbana e Roberto Cavalli. The company, stock quoted from november 1997, is part of a holding that manages a group of firms operating in the fields of design, creation and supply of high fashion apparels. It is the most important in the holding, and has behind more than thirty years of experience in the field of fashion; it has a workforce of more than one thousand and at present contributes to total sales of the holding with a share of more than 70%.

The company designs (in cooperation with maisons), manufactures and supplies a wide range of casual apparel products and accessories for man and woman, mainly targeted to youth. Articles of clothing produced by the firm are jeans, trousers, skirts, items of knitwear, tracksuits, sweatshirts, T-shirts.

The brands under which the products are commercialized benefit from a wide and consolidated renown, especially in the youth market; this allowed to the company to reach in a few years remarkable financial results and to establish as one of the main entrepreneurial realities in South Italy in the field of manufacturing and supply of brand apparel products and designer luxury accessories.

Apparel market, in which the company operates, is characterized by the presence of few subjects; in this market products differenziates from each other on the basis of look, brand, design and supply exclusivity. In other terms, luxury apparel market is a niche market where selling price has little importance with respect to other factors such as style, line peculiarity, brand renown; generally, price policies are absent in this market: competition is carried out resorting to other means, such as discounts, sales promotions, advertising.

In order to preserve style and model diversities which characterize company products, an internal structure based on cells was devised, where each cell is involved with the development of a single product line. Around sixty employees work on average in each cell, including creatives, designers, draftsmen, personnel in prototype departments and commercial services. These cells, like many factories inside the company, have each one its own personnel and structure; operating in a completely independent way from each other, they represent a strong point of the company. This organization allowed to the company to reach a high grade of flexibility, that makes possible the production and supply of a new product simply by organizing a single cell, without interference with the other cells' activities.

Each cell is coordinated and managed by a *project manager* who controls the regular development of operations in the cell; each step in the manufacturing cycle, in turn, is directed by a *function responsible* to whom refer the employees in the cell. This organization, together with the sophisticated systems available for production planning and material requirement planning and thanks to the short times of working of external shops, allowed to the company to organize the production phase so that only articles sold to customers during sales campaigns are manufactured, avoiding in this way the storage of raw materials and finished products and reducing, therefore, commercial risk.

3.1. Process reengineering - the new internal high productivity shop

Pressed from the requirements of Quick Response, the Company, who previously relied heavily on outsourcing, has explored the feasibility of increasing internal capacity in order to exploit the benefits above mentioned.

Consistently with available human resources, and available space in the Company industrial buildings, in order to obtain articles at low production costs, the possible choice of the articles to be re-insourced had to be carried out among a range of high value casual apparels, for which it would be possible the set-up of a production line that would allow large production volumes. From a detailed analysis of the articles produced by the company, the apparels suitable to large scale manufacturing resulted the denim five-pocket jeans.

A wide range of industrial machines for jeans manufacturing is available, provided with special equipments and very fast (2500÷4500 stitches/minute) which allow for remarkable reductions in manufacturing times, reducing the costs for workforce and maintaining a constantly high quality standard. These are automatic machines that carry on complex operations such as series joining of buttons and rivets, folding and sewing of back pockets and labels, the decorative stitching on back pockets, buttonholes realization, the making and sewing of loops and the joining of the belt with the four quarters of the article. The use of these machines ensures the maximum working efficiency of the employees, allows for a great reduction in physical stress, a better quality in the product and an increase in production levels and therefore in sales.

Five-pocket jeans may be manufactured on a line production, because the production mix consists of only two models (one with buttons and the other with zip fastener) and their manufactuting cycles differ only for the operations of buttons joining/zip stitching. All the machines can be arranged in an assembly line that allows for a high regularity in materials flow and a reduction in workforce needed and in transport activities.

Daily production volume for the new shop have been defined on the basis of market and financial considerations, which enabled to define the amount of extra productive capacity required to comply with the above cited quick response requirements. On the basis of these considerations, the high productivity shop sould manufacture around one thousand of jeans every day.

At present, daily market demand for these articles covered by the Company is around seven thousands: four thousands will remain in outsourcing from italian shops, two thousands from countries outside European Union.

3.2. Jeans manufacturing process

The whole jeans manufacturing cycle includes a sequence of different phases, that only in part are carried out inside the Company. A standard production comprises article manufacturing, washing, dyeing and finishing Non standard production may include printing of motifs on the fabric after the dyeing phase or particular processings carried out in order to confer *used look* to the jeans.

Object of the present work is the phase of manufacturing only.

Jeans manufacturing is the chronological sequence of assembly operations needed to transform raw materials in finished product; raw materials for jeans are pieces of denim cloth and lining, buttons, zip and accessories; pieces are obtained from by cut from bolts, while the other components are directly acquired from the market.

A five-pocket jeans is made of 38 components, in the case of buttons model, or 35 in the case of zip model; besides the handling and assembly, auxiliary operations are required, which consist in the preparation of detached pieces, stamping of package, sewing threads cutting etc.

Manufacturing process begins with the making of paper pattern, that is the drawing on paper of all cloth pieces needed for jeans. In the past paper pattern was made by hand and afterwards applied on the cloth piece for the cut. Today there is a certain diffusion of CAD instruments for the development of paper patterns, in which the cloth utilization is optimized through algorithms which dispose the various parts minimizing scraps and keeping into account the preferential directions for cut (in weft and warp) in order to obtain the proper aesthetic effect. The reference paper pattern is developed for size 34 (measure of the half waist, in inches), considered as medium size. The paper patterns for all other sizes are developed automatically by CAD system, properly scaling the medium size dimensions. The development of models of various sizes and therefore the paper pattern preparation depends on the number of sizes to be produced and by the numer of articles for each size; in general, sales volumes for each size assume a Gauss distribution around the central size, therefore number of articles per size in each production order will be variable: a major number in central sizes, a minor number for large and small sizes.

Paper pattern creation is very important in order to foresee the consumption in raw materials. In fact, on the basis of paper pattern and of the volumes to be produced in each size, warehouse can define the material requirements for the production and issue orders to the suppliers.

The paper pattern to be sent to the machine for the cutting operation must include all the sizes contained in the production order.

The operation preceding the cut consists of a preparation of a thick mat made of many superimposed pieces of cloth and the paper pattern on the top; the cut of the pieces is carried out using a work top, 20 meters long, showing tiny holes through which a pneumatic system, can create vacuum under the mat in order to keep it together during the cutting operations or blow air under it, in order to make easy the mat handling operations.

The cloth bolts (having heights variable in the range 80 - 200 centimeters and lengths of arount 100 meters) are unrolled, cut at the desired length and superimposed to make the mat. For a five-pocket jeans the average height of the cloth bolts is 1,40 m and the consumption, for a medium size article, is around 1,25 m, while the scrap is in the range 12 - 18%, as a function of the number of sizes or models present on the paper pattern.

After the cut, all the pieces are separated and the packages of detached pieces are transported to the manufacturing department, where all the machines are organized in a line respecting the sequence prescribed by the assembly cycle.

The jeans assembly cycle includes a series of around thirty operations that, except some cases, must be carried out in sequence, in different stations.

The whole assembly process may be summarized as:

1. parallel assembly of front pockets and back quarters;
2. assembly of front quarters;
3. assembly of front pockets;
4. parallel assembly of front two quarters and rear two quarters;
5. assembly of front and rear through side stitching
6. assembly of belt and loops.

The complete list of operations for the article assembly can be found in Table 2.

3.3. Time study by TMC

In order to define task durations, a detailed time study was carried out using TMC (ISVOR - FIAT) (*Tempo dei Movimenti Collegati* or, in english, Time of Linked Movements). TMC is a work evaluation method based on standard times. It has been developed at FIAT in order to overcome the difficulties in application of MTM, maintaining however its precision.

TMC application takes however for granted the knowledge of MTM system, because the two methods are based on the same basic rules. The basic actions in TMC are: move (M), auxiliary movements (AM), position (P), disengage (DE), turn (T) and body movements (BM). Each action may show a little, medium or big difficulty to be carried out: the time necessary to perform an action, expressed in thousandths of minute, is function of its difficulty.

Times evaluated by means of TMC do not include extra times assigned for rest, therefore, in order to carry out a correct evaluation of the resources employed in the line, and in particular of the number of employees, it will be necessary to keep into account this extra time.

In Table 1 TMC standard times are resumed.

Table 1 - Standard times in TMC

TMC				
ACTION		***Difficulty (*)***	***Symbol***	***Time (**)***
MOVE (M)	*WRIST* *0 ÷ 14 cm*	*e* *m* *d*	*Mwe* *Mwm* *Mwd*	*9* *13* *16*
	FOREARM *15 ÷ 35 cm*	*e* *m* *d*	*Mfe* *Mfm* *Mfd*	*16* *19* *22*
	ARM *36 ÷ 60 cm*	*e* *m* *d*	*Mae* *Mam* *Mad*	*22* *26* *29*
	SHOULDER *greater than 60 cm*	*e* *m* *d*	*Mse* *Msm* *Msd*	*29* *33* *36*
AUXILIARY MOVEMENTS	*REGRASP* *SIMULTANEOUSNESS* *WEIGHT OR RESISTANCE* *OBSERVE* *PRESS BUTTON*		*RG* *SI* *WR* *OB* *PB*	*4*
	APPLY PRESSURE		*AP*	*6*
POSITION (P)		*e* *m* *d*	*Pe* *Pm* *Pd*	*5* *12* *28*
DISENGAGE			*DE*	*4*
TURN (T)	*WRIST*		*Tw*	*6*
	OTHERS		*To*	*10*
BODY MOVEMENT (BM)		*e* *d*	*BMe* *BMd*	*8* *18*

(*) e=easy, m=medum, d=difficult (**) Expressed in 1/1000 min

Particular attention was paid to the organization of work areas. Based on the principle that movements must be as simple as possible, in fact, the location of tools, pieces and all what is necessary to the work execution has been foreseen inside the area of maximum comfort for the operator: that area delimited by circles centered on the elbows of operator's arms (along the bust) and having radius equal to the distance from elbow to knuckles.

Cycle time at each station was determined as the sum of standard times of operations assigned to the station.

Basic actions considered by TMC and necessary to the development of assembly operations are move, position and press treadle (considered as an easy body movement); in case of simultaneous actions, the time of longest action was assumed.

Move action was considered at a mean difficulty grade for detached pieces of cloth (such as small pocket, back pockets, lining, loops and belt), because these are thin objects, placed on a flat surface; for the other parts the action move was considered at an easy grade of difficulty.

In order to estimate the time required for sewing, average velocity of sewing machine V_{sewing} (stitches/min) was considered; for a stitch lenght L_{stitch} (mm/stitch) and a sewing lenght L_{sewing} (mm), the sewing time T_{sewing} (min) is given by:

$$T_{sewing} = \frac{L_{sewing}}{V_{sewing} \times L_{stitch}} \qquad (1)$$

All the times have been determined considering a manufacturing cycle for an article of medium size (34). It may be considered that times for handling in work places are the same for all sizes, therefore variations in time with respect to the medium size are due only to the sewings.

For dimensioning of manufacturing resources times referred to the medium size may be considered because production volumes are on a Gauss distribution whose mean value is the medium size and also because sewing times grow up as size grows up and therefore mean time of manufacturing may be assumed equal to the one of medium size.

In Table 2 results for TMC analysis on assembly operations are reported. In the same table extra times and standard time for each operation are summarized.

Extra times to be assigned to cycle operation times are three: physiological, for physical fatigue and for attention fatigue. For the first one a uniform value of 3% was assumed. The other two have been assumed each one as sum of three components: a base value of 3%, a value of 1,5% to keep into account the conditions of exposition to noise and a value of 2,5% in the operations in which the operator must stay stood. In the heaviest operations, therefore, the sum of all these extra times assumes a value of 17%.

Table 2 – Assembly operations and their times, evaluated by means of TMC

Task	***Description***	***Time (min.)***		***Extras (%)***	***Standard time (min.)***	
		Zip model	***Buttons model***		***Zip model***	***Buttons model***
1	*Stamping and distribution to stations*					
2	*Small pocket rim execution*	*0,038*	*0,038*	*0,17*	*0,044*	*0,044*
3	*Sewing of small pocket upon right pocket lapel*	*0,182*	*0,182*	*0,12*	*0,204*	*0,204*
4	*Sewing of two lapels front pockets*	*0,111*	*0,111*	*0,12*	*0,124*	*0,124*
5	*Sewing of lapels upon linings*	*0,264*	*0,264*	*0,12*	*0,296*	*0,296*
6	*Sewing of front pocket bags*	*0,347*	*0,347*	*0,12*	*0,389*	*0,389*
7	*Turning pockets inside out*	*0,135*	*0,135*	*0,12*	*0,151*	*0,151*
8	*Sewing of buttonrow and right feint ***		*0,214*	*0,12*	*0,000*	*0,240*
9	*Sewing of right feint and zip support **	*0,188*		*0,12*	*0,211*	*0,000*
10	*Sewing of zip upon support **	*0,129*		*0,12*	*0,144*	*0,000*
11	*Sewing of four buttonholes on left feint ***		*0,327*	*0,17*	*0,000*	*0,383*
12	*Two rear pockets rim execution*	*0,1*	*0,1*	*0,17*	*0,117*	*0,117*
13	*Decorative stitching on rear pockets*	*0,178*	*0,178*	*0,17*	*0,208*	*0,208*
14	*Sewing of front right (feint position)*	*0,088*	*0,088*	*0,12*	*0,099*	*0,099*
15	*Sewing of two front pockets (pocket rim)*	*0,277*	*0,277*	*0,12*	*0,310*	*0,310*
16	*Sewing of buttons support ***		*0,157*	*0,17*	*0,000*	*0,184*
17	*Sewing of left feint ***		*0,157*	*0,17*	*0,000*	*0,184*
18	*Sewing of zip support **	*0,165*		*0,12*	*0,185*	*0,000*
19	*Decorative stitching on zip cover **	*0,113*		*0,17*	*0,132*	*0,000*
20	*Sewing of front two quarters with zip **	*0,195*		*0,12*	*0,218*	*0,000*
21	*Sewing of front crotch*	*0,149*	*0,149*	*0,12*	*0,167*	*0,167*
22	*Sewing of strengthening stitches on feint*	*0,138*	*0,138*	*0,12*	*0,155*	*0,155*
23	*Sewing of front left and right (outside legs)*	*0,389*	*0,389*	*0,12*	*0,436*	*0,436*
24	*Sewing of rear pockets*	*0,451*	*0,451*	*0,17*	*0,528*	*0,528*
25	*Sewing of two rear yokes*	*0,297*	*0,297*	*0,12*	*0,333*	*0,333*
26	*Sewing of right crotch*	*0,117*	*0,117*	*0,12*	*0,131*	*0,131*
27	*Sewing of rear left and right (outside legs)*	*0,389*	*0,389*	*0,12*	*0,436*	*0,436*
28	*Sewing of legs inside*	*0,303*	*0,303*	*0,12*	*0,339*	*0,339*
29	*Felling of inside legs seam*	*0,248*	*0,248*	*0,12*	*0,278*	*0,278*
30	*Sewing of outside legs*	*0,321*	*0,321*	*0,12*	*0,360*	*0,360*
31	*Sewing of two sides*	*0,213*	*0,213*	*0,12*	*0,239*	*0,239*
32	*Sewing of strengthening stitches on sides*	*0,144*	*0,144*	*0,12*	*0,161*	*0,161*
33	*Turning garment inside out*	*0,125*	*0,125*	*0,17*	*0,146*	*0,146*
34	*Preparing band for loops*	*0,118*	*0,118*	*0,12*	*0,132*	*0,132*
35	*Stitches union*	*0,073*	*0,073*	*0,12*	*0,082*	*0,082*
36	*Sewing of belt*	*0,16*	*0,16*	*0,12*	*0,179*	*0,179*
37	*Finishing of two belt corners*	*0,284*	*0,284*	*0,12*	*0,318*	*0,318*
38	*Preparing and sewing five loops*	*0,281*	*0,281*	*0,12*	*0,315*	*0,315*
39	*Sewing of belt buttonhole*	*0,105*	*0,105*	*0,17*	*0,123*	*0,123*
40	*Sewing of two bottoms rim*	*0,207*	*0,207*	*0,12*	*0,232*	*0,232*
41	*Sewing of labels upon belt*	*0,298*	*0,298*	*0,17*	*0,349*	*0,349*
42	*Applying button upon belt **	*0,09*		*0,12*	*0,101*	*0,000*
43	*Applying five buttons ***		*0,288*	*0,12*	*0,000*	*0,323*
44	*Applying six rivets on front*	*0,201*	*0,201*	*0,12*	*0,225*	*0,225*
45	*Cutting of thread and final control*	*0,6*	*0,6*	*0,17*	*0,702*	*0,702*
** only zip model ** only buttons model*						

3.4. Determination of cycle time

The design annual production volume of the line (V) is 230.000 jeans. It is foreseen that the shop will work on a single daily shift, for 230 days at year. Assuming for the global efficiency of the line a value 90% (which keeps into account the stops of line and production scraps), the production capacity required to the line will be:

$$C_{P\,year} = \frac{V}{h} = \frac{230000}{0{,}90} = 255556 \left[\frac{units}{year}\right] \tag{2}$$

to which corresponds a production rate of:

$$R = \frac{C_{P\,year}}{230 \times 8 \times 60} = \frac{255556}{110400} = 2{,}31 \left[\frac{units}{min}\right] \tag{3}$$

and a cycle time:

$$T_C = \frac{1}{R} = 0{,}432 \left[\frac{min}{unit}\right] \tag{4}$$

Examining the standard times for the operations in table 2, it is evident that some operations require times not compatible with the cycle time imposed to the line. For these operations the stations will have to be replicated in order to obtain for average times in operations execution values comparable with the line cycle time. In particular, operations which require duplication in resources are nos. 23, 24, 27 and 45.

3.5. Production resources sizing

For the sizing of production resources, the times previously evaluated for the operations have been assigned to the single stations using the line balancing method from Kilbridge and Wester (1961).

In Figure 1 precedence diagrams utilized by this method are depicted for both buttons and zip model.

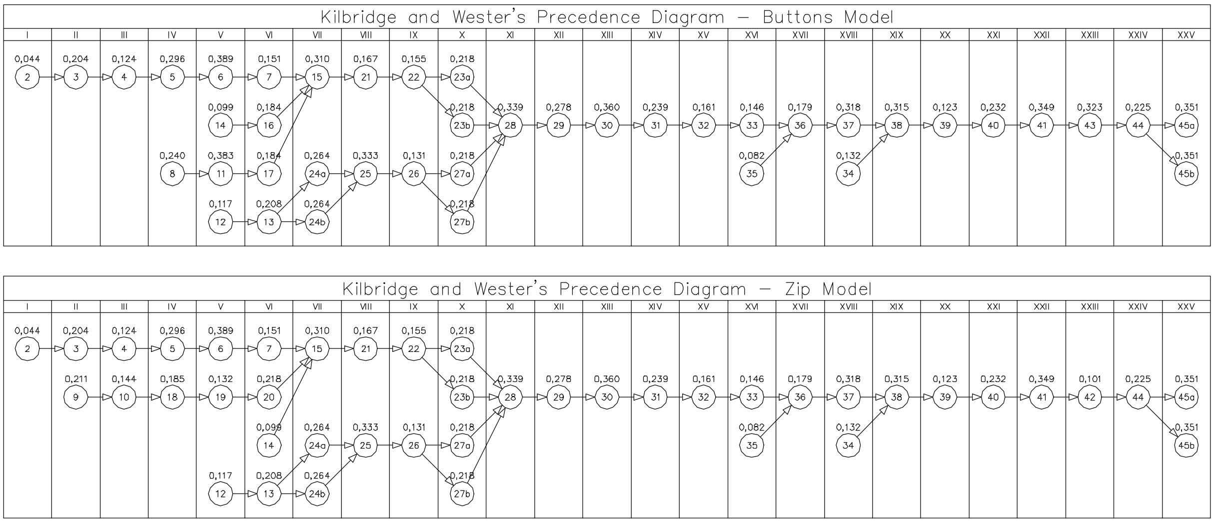

Figure 1. Kilbridge and Wester's precedence diagrams for the jeans assembly process

From these diagrams the assignment of operations to the employees reported in Table 3 has been obtained. A workforce of 30 employees have been assumed.

Besides the assembly operations, auxiliary operations are needed, which must be carried out by employees not working directly on the line. These operations are: preparation of detached pieces, stamping, preparation and distribution of the loading units, feeding and control of work in progress.

The preparation of detached pieces consists in picking the wrapped up pieces from a container, untieing them, and depose the packages ordered by size on the work top for the stamping; after the package stamping, loading units to be transferred to the stations are prepared. The sum of auxiliary times per shift, including the extra times, was found to be remarkably less than the 480 minutes of work available in the shift. Only one employee is therefore sufficient to carry out the auxiliary operations.

Two employees are needed for plant surveying: a shop manager with function of surveying and control on production, production advancement, and inventory, and an employee for maintenance who carries out mechanic and electricist functions.

Maximum saturation (94%) concerns operator no. 21.

The average line saturation may be expressed, for button model and zip model manufacturing, as:

$$S_{button,T_c=0,432} = \frac{\sum_{i=1}^{N_{station}} T_{station_{i,button}}}{N_{station} \cdot T_c} = 0{,}741 \qquad S_{zip,T_c=0,432} = \frac{\sum_{i=1}^{N_{station}} T_{station_{i,zip}}}{N_{station} \cdot T_c} = 0{,}735 \tag{5}$$

Table 3 – Line balancing

	BUTTON MODEL				ZIP MODEL			
Empolyee	*Task*	*Time*	*Tot. time*	*Saturation*	*Task*	*Time*	*Tot. time*	*Saturation*
1	2	0,044	0,372	86%	2	0,044	0,372	86%
	3	0,204			3	0,204		
	4	0,124			4	0,124		
2	5	0,296	0,395	91%	9	0,211	0,355	82%
	14	0,099			10	0,144		
3	8	0,240	0,357	83%	5	0,296	0,296	69%
	12	0,117						
4	6	0,389	0,389	90%	18	0,185	0,317	73%
					19	0,132		
5	11	0,363	0,363	84%	6	0,389	0,389	90%
6	7	0,151	0,335	78%	12	0,117	0,325	75%
	16	0,184			13	0,208		
7	13	0,208	0,392	91%	7	0,151	0,369	85%
	17	0,184			20	0,218		
8	15	0,310	0,310	72%	14	0,099	0,363	84%
					24b	0,264		
9	24a	0,264	0,264	61%	15	0,310	0,310	72%
10	24b	0,264	0,264	61%	24a	0,264	0,264	61%
11	21	0,167	0,322	75%	21	0,167	0,322	75%
	22	0,155			22	0,155		
12	25	0,333	0,333	77%	25	0,333	0,333	77%
13	23a	0,218	0,218	51%	23a	0,218	0,218	51%
14	23b	0,218	0,218	51%	23b	0,218	0,218	51%
15	26	0,131	0,349	81%	26	0,131	0,349	81%
	27a	0,218			27a	0,218		
16	27b	0,218	0,218	51%	27b	0,218	0,218	51%
17	28	0,339	0,339	78%	28	0,339	0,339	78%
18	29	0,278	0,278	64%	29	0,278	0,278	64%
19	30	0,360	0,360	83%	30	0,360	0,360	83%
20	31	0,239	0,400	93%	31	0,239	0,400	93%
	32	0,161			32	0,161		
21	33	0,146	0,407	94%	33	0,146	0,407	94%
	35	0,082			35	0,082		
	36	0,179			36	0,179		
22	34	0,132	0,132	31%	34	0,132	0,132	31%
23	37	0,318	0,318	74%	37	0,318	0,318	74%
24	38	0,315	0,315	73%	38	0,315	0,315	73%
25	39	0,123	0,355	82%	39	0,123	0,355	82%
	40	0,232			40	0,232		
26	41	0,349	0,349	81%	41	0,349	0,349	81%
27	43	0,323	0,323	75%	43	0,323	0,323	75%
28	44	0,225	0,225	52%	44	0,225	0,225	52%
29	45a	0,351	0,351	81%	45a	0,351	0,351	81%
30	45b	0,351	0,351	81%	45b	0,351	0,351	81%

The line has a further capacity to exploit. In particular, assuming a cycle time for the line of 0,410 min, compatible with the times of single operators reported in table 3, the real production capacity for the line will be given by:

$$C_{P\ year} = \frac{230 \times 8 \times 60}{0{,}410} = 269268 \left[\frac{units}{year}\right] \quad (6)$$

which will give the annual production volume:

$$V = 269268 \times 0{,}9 = 242341 \left[\frac{units}{year}\right] \quad (7)$$

The average line saturation, with this new value for cycle time, becomes:

$$S_{button,T_c=0,410} = \frac{\sum_{i=1}^{N_{station}} T_{station_{i,button}}}{N_{station} \times T_c} = 0{,}781 \qquad S_{zip,T_c=0,410} = \frac{\sum_{i=1}^{N_{station}} T_{station_{i,zip}}}{N_{station} \times T_c} = 0{,}774 \tag{8}$$

The workforce needed by the high productivity shop will be: 1 Shop Manager, 1 Maintenance Manager, 1 Transport employee, 30 Line Operators, 1 Employee at Cutting station.

3.6. Economic Considerations

Although the reasons which justify the internal capacity re-insourcing set aside from strict profitability of the investment, concerns as are intended to gain a competitive advantage may be useful also to evaluate its economic feasibility. It will be therefore necessary to compare the costs of the internal production option with the costs of resorting to external suppliers.

Investments are needed for building and machines and equipments acquisition. The building is already existing and only adaptation costs for auxiliary, general and special plants are required, amounting to around 120.000 €. The investment in machines and equipments has been evaluated as 420.000 €. Periods of amortization have been assumed of ten years for machines and thirty years for building. Workforce costs amount to 732.000 €/year. Energy costs have been determined in 5.000 €/year. For environment heating a cost of 10.000 €/year has been supposed. Maintenance costs have been assuming to amount to 3% of investment in machines.

Total Capital Investment (TCI) therefore amounts to 540.000 €, with an annual amortization (AA) value of 46.000 €, while Total Operating Cost (TOC) amounts to 759.600 €.

It follows that the gross internal manufacturing cost per piece is:

$$c_{im} = \frac{AA + TOC}{C_{P\,year}} = \frac{46.000 + 759.600}{240.000} = 3{,}36 \left[\frac{€}{unit}\right] \tag{9}$$

which has to be compared to

The current market cost of third parties manufacturing is around 3,55 [€/unit], therefore a net saving 0,19 [€/unit] may be obtained re-insourcing this manufacturing process.

Total Operating Cost above evaluated does not involve raw materials because the cost per piece for internal manufacturing has to be compared to the one for external manufacturing which is carried out by third parties on raw materials supplied by the company.

A differential economic analysis was carried out on the two aforementioned alternatives.

With the preceding economic assumptions, the Net Discounted Cash Flow trends shown in figure 2 result, having a Net Present Value ranging between -47.000 € and 186.000 €, corresponding to interest rates (i) between respectively 16% and 6% per year.

$$NPV = -TCI_{im} + \sum_{k=1}^{10} \frac{TOC_{em} - TOC_{im}}{(1+i)^k} \tag{10}$$

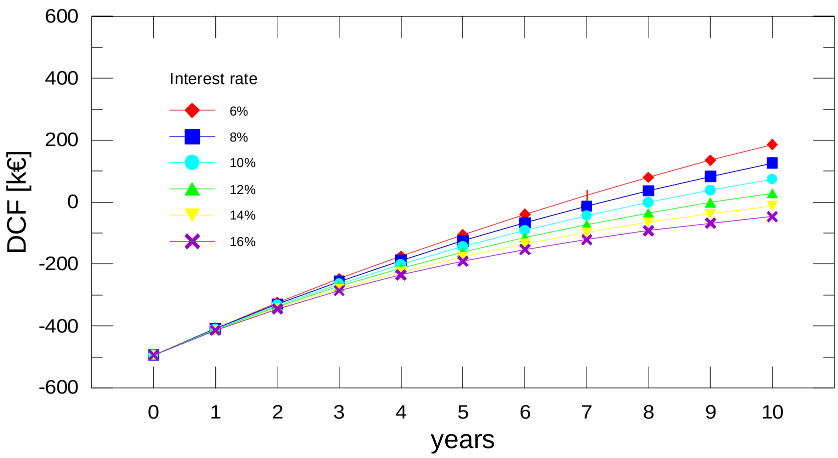

Figure 2. Differential investment DCF and NPV.

4. Conclusions

In the perspective of Quick Response, a proposal of re-insourcing of jeans manufacturing in a large enterprise is described in this work. The solution, which involves undoubted advantages in the responsiveness of the company, is technically feasible by means of a high productivity shop dimensioned for the requirements of the company.

A differential economic analysis carried out on the two alternatives of internal and external manufacturing demonstrated that the re-insourcing may also be a profitable investment.

In conclusion, it has been demonstrated that, in counterdendency with the usual manufacturing outsourcing operated in the textile industry, the partial re-insourcing in Quick Response perspective may be useful and economically sustainable and represents an alternative which should be carefully evaluated.

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