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Product-driven Process Value Analysis

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Abstract
The paper describes a methodology to support business process re-engineering by mapping product requirements to product development phases in order to analyze their contribution to value creation. The methodology has been already validated by the authors in different industrial sectors through real case studies [1], that were all characterized by well established business processes, needing improvements to preserve their competitiveness in the marketplace. In this paper the effectiveness of the methodology in identifying process criticalities is tested with regards to industrial processes experiencing under capacities in satisfying the market demand as well as concerning not yet established business ideas. The task is performed by considering the wood pellet production process as a case study.

Keywords:
Process Value Analysis, customer satisfaction, Business Process Re-engineering, product requirements

1 INTRODUCTION

All the products have to pursue continuous improvements in order to satisfy new customer requirements or novel market demands concerning their whole lifecycle. This task implies an evolution of the production process at different levels. In some circumstances minor reorganizations in the design or production phases can be sufficient to fulfil the evolving product requirements; besides, these actions usually bring only to limited improvements mainly focused on preserving the competitiveness of the product in the marketplace.

In other market circumstances the companies have to develop more remarkable innovations. Boundary conditions, such relevant discontinuities in customer perceived value and preferences, lead to the implementation of radical technological changes [2]. Besides, limitations of available resources are a common trigger for impending transitions of mature technical systems [3] or even established service industries [4]. Disruptive innovations can be brought also by performing a careful analysis of the possible aspects of value that consumers might care about, such as way of using, further technical or emotional features, resources consumption, maintenance, environmental impact, customer care, end of product lifecycle. Such approach, that is viable to create new market opportunities, implements a product planning strategy aimed at making the competition irrelevant, that determines a new value curve strongly different than the previous one [5].

However, novel product ideas often show relevant problems to access market due to a large amount of factors such as design or manufacturing costs [6], organizational issues [7], required technologies or materials [8], relevant drawbacks [9], resources consumption [10]. All these kinds of limitations represent significant hurdles to exploit new business opportunities, notwithstanding the realized products or the delivered services are viable to occupy promising market space.

Consequently the implementation of new product ideas requires a radical transformation of the production process encompassing the reorganization of its phases and the reallocation of the resources, that have to be oriented towards the fulfilment of the identified customer requirements. Thus the task includes recognizing new productivity requirements, product performances to be enhanced, new functions to be fulfilled, new properties or features of the system. In order to prioritize the actions to be taken, the guidelines for performing the changes of the production process have to be driven through the identification of value bottlenecks. With the aim of performing this task and defining re-engineering activities aimed at obtaining improvements of a business process that are focused on the impact that each phase has on the value generated for the users, a methodology based on Process Value Analysis has been developed by the authors [1]. The proposed approach allows the identification of proper metrics to assess a set of product/service requirements intended to ensure customer satisfaction. On the base of such metrics the evaluation of the impact of each phase in the perceived value of products and/or services is performed with respect to the employed resources. The results of this assessment are used to systematically synthesize suitable guidelines for both process evolution strategies and resource reallocation activities, allowing to preserve or improve market competitiveness of products and/or services.

Several case studies in very different industrial sectors have been analyzed with the aim to test the robustness of the proposed method. These case studies were mainly related to well established business processes, needing improvements to preserve the competitiveness of the delivered products/services in a crowded marketplace.

In this paper the application of the methodology in an emerging field is presented, i.e. the woody pellet production process. This sector presents high business opportunities in Italy since the market demand of such kind of energy sources has grown dramatically in the last five years. However the poor performance arising out of the industrial processes still under development, doesn't allow the complete exploitation of the biomass resources, thus the market demand of woody fuels remains unsatisfied. In such context the paper tests the applicability of the developed approach also for industrial processes experiencing such kind of under capacities, as well as concerning not yet established business ideas.

The paper presents: in section 2, a brief literature review of tools and methods dedicated to support business process re-engineering tasks; in section 3, the approach developed by the authors in a version customized according to the objectives faced in the case study; a detailed description of its application to the production process of solid woody fuel in Italy in section 4. The results arising from the case study case are discussed in section 5, that includes also the conclusions.

2 LITERATURE REVIEW

Many methods, that are mainly related to the field of the Business Process Re-engineering (BPR) [11-13], have been developed aimed at addressing redesigning and innovation tasks of business and manufacturing systems.

An integrated multidimensional process improvement methodology has been proposed in [14] to address the yield management, process control and cost management problems for a production process. The Total Quality Management (TQM) is used to manage the cost of the system according to the quality requirements and a discrete event simulation is used to perform process re-engineering and process improvement.

In [15] a method has been proposed which supports the practitioners in developing a new improved business process starting from the current design based on a heuristic approach. The method has been extrapolated from different successful best practice approaches to the BPR problems available in the literature survey. They have been synthesized in a check list to support process redesigning by taking into account different management approaches: Total Cycle Time compression, Lean Enterprise and Constraints Management.

In [16] an investigation of BPR methodologies employed in different companies making products on engineering to order basis (ETO) that typically find business opportunities by the ability to respond to customer requirements, has been performed. The results show that BPR methodologies cannot be applied to such kind of companies since they are not able to manage different business units as in the case of collaborating companies.

A methodology to assist the user in identifying the most appropriate lean manufacturing tools and techniques to address the problems of a particular company through a quantitative compatibility assessment has been proposed in [17]. The results confirm that lean manufacturing tools may have a major impact only on specific areas of the business but not for companies experienced problems in areas such as under capacity, scheduling and innovation in products and processes, which are all topics, that are not directly influenced by lean manufacturing methods.

The approach based on Balanced Scorecard (BSC) [18] provides a systematic tool for BPR by combining financial and nonfinancial performance indicators in a coherent measurement system. Four metrics are defined according to a selected strategy, and the company's processes are aligned towards this strategy. The company is evaluated in four areas: the financial perspective; the customer satisfaction; the internal business process view based on the concept of the value chain; a final index comprising the innovation and learning perspective. As stated in [19] BSC suffers from limits based on invalid assumptions about the innovation economy: its rigidity, its conception of knowledge and innovation as a routine process and its focus on the internal processes of the company, neglecting the relationships with the environment, make the BSC an insufficient tool for understanding and dealing with the innovation economy.

A number of works approach the problem of dealing with concurrent issues in terms of costs management and product requirements; a recent example is [20], where the integration of Value Engineering and Target-costing techniques is proposed to support the product development process in an automotive company. Such a methodology was applied to a case study aimed at improving costs and performances of a vehicle engine-starter system, according to customer and company needs.

Several works in literature demonstrate that BPR has failed to meet its expectations; among the others, [21] shows that 60–80% of BPR initiatives have been unsuccessful. The most frequent and harsh critique concerns the strict focus on efficiency and technology and the disregard of people in the organization that is subjected to a reengineering initiative. Very often the label BPR was used for major workforce reductions with the aim to decrease organizational and production costs, instead of being able to suggest any kind of improvement based on process innovation. Moreover the analysis performed in [22] suggested that in order to obtain successful BPR initiatives, redesign efforts should be focused not only on cost and time reduction but mainly on the areas of the business process having the most direct impact on customer value. These results show that managers must reengineer their core processes starting from the customer perspective.

In such a context the Product and Service Systems (PSSs) approach has been developed in [23] with the aim to provide a product additional value, base a growth strategy on innovation in a mature industry and improve the total value for the customer thanks to increased servicing. However there are few examples of complete PSSs designed on a life cycle basis in companies. This is due to a number of uncertainties concerning the characteristics of the PSSs, among the others:

- readiness to adopt the PSSs into a company's strategic decisions. The shift from selling products to providing PSS entails substantial changes in the companies' structure and organisational frameworks, production and marketing strategies;
- readiness to accept the PSSs by consumers; little research has been conducted on evaluating the impact of PSSs paradigms and their profitability for consumers.

In order to overcome these limits a general methodological framework for PSSs design and implementation still requires to be developed.

Many other approaches available in literature suggest guidelines for business re-engineering activities mainly focused on cost reduction without taking into account any aspect of the benefits the product or service generates for customers.

3 METHODOLOGICAL PROPOSAL

The identification of value bottlenecks is performed by a classification of the business process phases based on the value they generate for the customer in terms of product requirements, taking into account the amount of the employed resources. The procedure for the identification of the phases that do (or do not) contribute at a proper extent to generate value along the business process can be summarized in the following steps:

1. information gathering, carried with proper techniques, allowing to determine the relevant process phases and the extent of the employed resources;
2. identifying relevant customer requirements and their relative importance in order to create value;
3. determining the degree at which the phases contribute to fulfil the previous mentioned requirements;
4. calculating the overall value of each phase;
5. evaluating the directions of improvement for the considered business process.

In the following a brief description of the above mentioned steps already proposed in [1] is reported, with a specific emphasis on the customization needed according to the objectives of this paper.

3.1 Gathering information and building the model of the current business process

The first step of the methodology consists in performing an accurate collection of the information about the process and its operations, such as EMS (energy, material, signal) flows, technologies involved, products and services delivered, knowledge management means and criteria and other resources. The information gathering allows to segment the business process in a set of phases.

If well-established business and manufacturing practices are usually documented in books and in the scientific literature, poor knowledge can be gathered within new, pioneering or under development industrial processes. Thus experimental data and the tacit knowledge belonging to enterprises' internal resources (managers, directors, but even employees) play a major role in collecting information for a starting business.

Within business and manufacturing processes it is recommended to employ proper modelling techniques, such as the ones of IDEF family, that play an unquestionable role in making the acquisition of knowledge related to the as-is state easier. Among these modelling tools, IDEF0 allows to create diagrams suitable to represent the functions performed within business and manufacturing processes. However the technique fits processes representation [24], since the system functions that can be modelled include activities, actions, operations.

IDEF0's graphical format with "box and arrows" allows within process modelling to schematize the operations involved (the boxes), as well as EMS flows and transformations, controls, employed technologies and personnel competencies (through the formalized arrows). Thanks also to its hierarchal representation of activities, that is useful in revealing further details of the business model, IDEF0 returns as an output the whole set of phases, univocally defined by their function and flows.

Although IDEF0 allows to highlight, along the whole business process, a large amount of inputs and outputs, in the context of this research, the analysis requires a more careful investigation about the resources employed in the system. The information about monetary flows, amount of labour, operational times, needs for physical space and the whole set of involved resources and harmful effects generated when performing the process (i.e. environment pollution, tools and machinery consumption) has to be summarized in the process model. Particular attention has to be paid towards those resources and drawbacks that constitute significant hurdles to access the market in consideration of the as-is process. The IDEF0 model has been here customized in order to map these flows of resources. It is worth to mention that in scientific literature there are several papers where the original formalism of the IDEF language has been customized according to the specific tasks or objectives to be faced, as in [25].

3.2 Identifying the benefits and the performance of the process

This step is addressed to evaluate the benefits generated by the business process in terms of their own contribution to determine customer perceived value and satisfaction. The task is accomplished through the evaluation of the value adding attributes pertaining the manufactured products or the delivered services.

In the investigation of potential new business the attention is firstly focused on satisfying the customer requirements at an extent comparable with further competitors, besides specific objectives of the developed project and the minimal technical attributes, requested by laws or other restrictions [26]. Since all these requirements represent attributes that the product should hold in order to access the market, it is assumed that the benefits originated from the business process reside in fulfilling these requirements.

According to this statement each requirement is indicated with the denotation CR and it is weighted by a relative relevance index (*R*) in accordance to its role in determining the contribute to let market access and to boost customer perceived value. A scale from 1 to 5 will be adopted for this purpose, whereas 5 represents the highest importance.

3.3 Identifying the phases' extent in generating benefits

In order to relate the business process steps with the value perceived by the customers, it is hereby remarked that each phase contributes totally or partially to ensure the product requirements. Thus, in the scope of business process re-engineering activities, the proposed procedure requires mapping the product attributes underlying the accomplishment of each CR. Subsequently the phases, properly identified in the step 1, that modify or somehow deal with those attributes are evaluated by the business process experts in order to define their relative contributions in fulfilling each CR. These relative contributions give the possibility to determine for each phase its own Phase Overall Satisfaction (*POS*), representing its extent to bring customer contentment and to gain market acceptance. The phase coefficients POS_j are calculated as follows

$$POS_j = \sum_i kij \times Ri \tag{1}$$

where:

- k_{ij} is the relative contributions addressed to the *j*th phase in ensuring the achievement of the ith CR;
- R_i represents the relative relevance index of the *i*th attribute.

3.4 Determining the overall value of the process phases

The purpose of this step is to perform a comparison among the process phases in terms of parameters related to customer satisfaction and the resources needed for their accomplishment. This task is accomplished by evaluating the ratio between the *POS* of each phase and the related resources that are employed; such approach is based on the logic of Value Analysis (VA) [27]. With respect to the traditional application of VA mainly addressed to evaluate the ratio between performance of a function and costs, in such context it is applied considering the total amount of resources spent by the business process phases to guarantee the CRs, as well as drawbacks and harmful effects arising in pursuance of the activities. Such modified ratio represents the degree of ideality of each phase as defined in the TRIZ Theory [28], thus representing an evolution of the well-ascertained value expression of VA, that relates just benefits and costs. Moreover, in its widest meaning, the degree of ideality indicates a ratio between the value delivered by a certain system and all types of expenses and investments needed to produce this value [29].

Within the context of business processes it is suitable to consider the whole range of resources spent (occupied space, information and know-how, labour time, energy, materials, dead times) and measure their extent, in order to use value and ideality formulations for calculating quantitative indicators. Long elapsed times to perform the phases can represent hurdles to gain competitiveness in the market. The activities duration has to be considered, although quick response strategies [30] are mainly focused to established business sectors, that include time among the most meaningful competitive factors, due to the need to speed up the continuous introduction of new items in the market. All the kinds of the other employed resources can be compared in terms of the expenses deriving from their employment, so to be evaluated with uniform units of measurement.

With regards to the harmful effects, they will be soundly considered in value calculation when representing barriers to access the market or problems affecting the stability of the system, as well as the repeatability of the process.

When resources costs, meaningful elapsed times and harmful effects coexist in the business process, experts have to weigh their relative relevance, introducing corrective coefficients for the calculation of phases overall value.

Due to the previous evaluations, the overall value of the *j*th process phases (POV_j) is calculated through the formula (2):

$$POVj = \frac{POSj}{c \times Cj + t \times Tj + h \times HFj} \quad (2)$$

where:

- C_j represents the total costs incurred to carry the *j*th phase;
- T_j indicates the time spent in completing the *j*th phase;
- HF_j is the estimated extent of harmful effects arising from the *j*th phase;
- *c*, *t* and *h* stand for the coefficients that measure the relevance of expenditures, elapsed times and drawbacks in hindering the market access.

The value of the latter coefficients depends on the maturity of the technology under analysis, as analyzed in [31].

3.5 Prioritizing the directions for improvement

This stage of the methodology is meant to rank the process phases according to the calculated values. The *POV* indicators are suitable to identify business process strong points and constraints among the phases. The phases showing a high *POV* rate can be considered to be tailored to the business process and their employed resources are well spent in generating customer satisfaction, whereas the ones with low scores can represent problematic issues and bottlenecks in the value creation process. By the point of view of value creation the most problematic phases have to be analyzed carefully, since they have the biggest priority in performing modifications for Business Process Reengineering. Through such analysis suitable actions can be defined to perform process re-engineering tasks focused to preserve/improve the value perceived by the customers.

4 CASE STUDY: WOOD PELLET PRODUCTION

Solid biofuel obtained by the sustainable exploitation of forest resources represents a relevant complementary source of energy to oil and its derivatives. In the last two years the market demand of solid biofuel in Italy has dramatically grown and it represents a business opportunity for a lot of rural areas: one of these is the Appennino Tosco-Emiliano. Two different kinds of solid biofuel are obtained by the exploitation of the forest resources and sawdust:

- wood chips: pieces of wood having overall dimensions of 25 X 30 X 20 mm, maximum moisture content of 20% in weight, average market price 70 €/Ton;
- pellets: cylinders of pressed sawdust having a diameter of 6 or 8 mm, height of 35 mm, moisture content of 10% in weight, average market price 180 €/Ton.

Table 1 shows an example of local exploitation of biomass resources, referring to a small area located in the Appennino Tosco-Emiliano (Italy). In this region the amount of biomass obtained by the sustainable exploitation of forests during a year, may constitute an energy source able to satisfy the needs of about 6600 housing units making them almost independent from the oil derivatives. The available resources are: wood sawdust having a very low content of moisture coming from wood industry and wood waste obtained by the maintenance operations of the forests and the urban green, that is supplied in form of pieces of tree and has a high moisture content.

A preliminary analysis of the business process showed that the wood waste is used mainly to manufacture wood chips, while pellets are just manufactured from sawdust. As shown in Table 1, the yearly availability of the wood coming from sawmills is smaller than the amount coming from forest and urban management. Actually the business process related to the production of woody fuels is able to satisfy the market request of wood chips, while a big deal of pellets market demand is still unmet.

Pellet production therefore constitutes a relevant case study to demonstrate the applicability of the methodology developed by the authors in the context of under-capacities.

Origin	Moisture content (in weight)	Estimated availability	Estimated availability after 10 years
Wood from industry processes	10%	5000	6000
Wood coming from forest management	35-50%	25000	50000
Wood coming from urban green management	45-50%	2000	10000

Table 1: woody biomass resources available in the Appenino Tosco-Emiliano (tons/year).

Each step of the method summarized in the previous section is presented in details hereafter.

4.1 Building the model of the current business process

The IDEF0 model of the manufacturing process is shown in Figure 1. The system modelling determines the segmentation of the process in six phases: A1 Trituration, A2 Purification, A3 Dewatering, A4 (second) Trituration, A5 Pelletizing, A6 Cooling and packaging.

According to Figure 1, the process used to produce the wood chips starts with the trituration (called “chipping”) of the wood biomass in order to obtain chips having overall size of less than 30 X 30 X 30 mm. The next phase is aimed at purifying the obtained wood chips by removing any kind of impurities (such as solid particles, glass, iron, etc.). In order to avoid fermentation, the moisture content is reduced to 20% in weight: dewatering is performed using thermal heating and at the end of the process the wood chips are cooled in air. In the next phase the wood chips are further triturated up to the size of the sawdust for the pelletizing phase. The pelletizing of the sawdust produces a not negligible heat due to the high friction of the extrusion die, thus the pellets require to be cooled at the end of the process before the final packaging.

The resources to make the system work properly range from energy to labour and space occupied by tools and machinery. In Table 2, the power consumption of each phase of the process is surveyed. The dewatering phase requires a high energy consumption in order to reduce the moisture content of wood chips from 50% to 20% in weight, the thermal process usually requires 3600 MJ for each ton of removed water. Also different relevant resources are indicated in the same Table, that shows that the pelletizing is accounted to a large involvement of human skills in terms of labour, experience and know how, while the machines addressed to perform the dewatering stage show the largest size.

Phase	A1	A2	A3	A4	A5	A6
Energy consumption (MJ/Ton)	54	18	1260	216	25.2	0
Personnel involvement (labour hours/Ton)	0,1	0,1	0,3	0,1	0,5	0,3
Space consumption (plant portion)	0,1	0,2	0,35	0,1	0,1	0,15

Table 2: resources consumption for each phase of the process.

As shown in the IDEF0 diagram (Figure1) there are some output flows of energy wasted from several phases of the process that constitute unexploited internal resources of the system (such as: the heat content discharged by the cooling phases, the heat content of the air ejected from the dewatering furnace, etc.) as well as the materials extracted by the purification process and the water obtained during the dewatering operations. While the materials extracted by the purification phase may constitute market opportunities, the thermal flows discharged during the process show temperatures that don’t allow their convenient recycle for other tasks of the process.

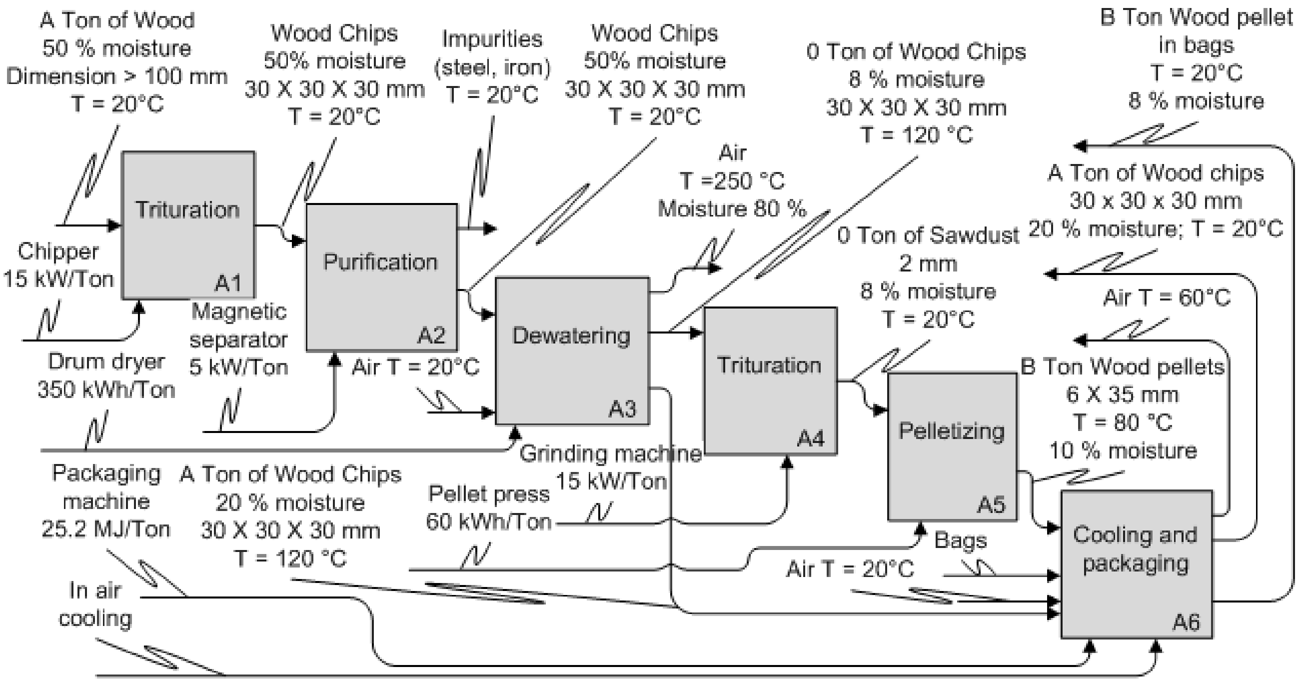

Figure 1: IDEF0 model for wood pellet manufacturing from renewable wood.

4.2 Identifying the benefits and the performance of the process

In the current business process, the set of the critical features to access market is constituted by five requirements. A suitable lower heating value, LHV (CR1), represents the main performance of wood pellets, since it is intended to deliver the main function of providing heat; this attribute holds the biggest importance and the correspondent relevance degree is 5. The sector experts have accounted with an importance level equal to 3 some characteristics of the product referred to the licensing laws, such as size (CR2), hardness (CR3) and brightness (CR4). At last the availability of wood pellets in bags (CR5) represents a further attribute for the manufacturing process, but it is accounted for a minimal degree of relevance (thus, 1). Table 3 summarizes the requirements and their relative importance.

Attribute	***Ri***
CR1 – LHV	5
CR2 - Size	3
CR3 – Hardness	3
CR4 – Brightness	3
CR5 - Availability in bags	1

Table 3: wood pellets attributes and their accounted relevance.

4.3 Identifying the phases' extent in generating benefits

As the methodological section describes, the phases' extent to generate satisfactory products is evaluated through the introduction of k_{ij} coefficients. Such coefficients are assessed by process meta-experts.

The estimation of the k_{ij} indexes takes in consideration that the most relevant CR (lower heating value), is determined mainly by the dewatering phase, while the first trituration phase gives a minor contribution. The assessment can be explained through the parameters influencing the performances of the dewatering process based on thermal heating (quantity of the evaporated water and the productivity): dimensions of the raw material at the inlet of the furnace and temperature of the process. CR2 (Size), CR3 (Hardness), CR4 (Brightness) are determined mainly by pelletizing since in this phase the sawdust is pressed and shaped up to the dimensions of the pellet. CR5 (Availability in bags) depends mostly on packaging and on the size of the pellet, determined by the pelletizing and the second trituration.

Table 4 summarizes k_{ij} coefficients, while Table 5 shows the calculation of POS_j indexes through (1), thanks to the values of R_i shown in Table 3.

Phase	**CR1**	**CR2**	**CR3**	**CR4**	**CR5**
A1	0,4	0,1	0,0	0,0	0,0
A2	0,0	0,0	0,1	0,2	0,0
A3	0,6	0,0	0,0	0,0	0,0
A4	0,0	0,2	0,0	0,0	0,0
A5	0,0	0,7	0,9	0,8	0,1
A6	0,0	0,0	0,0	0,0	0,9

Table 4: contribution of wood pellet production phases to fulfil the system requirements.

Phase	***POSj***
A1 - Trituration	2,30
A2 - Purification	0,90
A3 - Dewatering	3,00
A4 - Trituration	0,60
A5 - Pelletizing	7,30
A6 - Cooling and packaging	0,90

Table 5: accounted satisfaction (*POS* indexes) arising from each phase of wood pellet manufacturing process.

4.4 Determining the overall value of the process phases

The study of the business process has highlighted the main resources involved in the system.

The time to market doesn't represent a critical factor for the analyzed business process; moreover, the manufacturing of pellets from wood waste doesn't show remarkably longer times than their traditional production from sawdust. Thus the duration of the production phases is not considered relevant for the examined value creation process, as well as the undesired effects of the manufacturing phases (e.g. noise, vibrations, maintenance, etc), that aren't actually pointed out.

Therefore the phases' value estimation has neglected operating times and drawbacks, focusing the attention just on the employed resources. In other terms, the coefficients *c*, *t* and *h* don't play any role in this specific case study.

The resources consumption has been normalized assuming a reference production of 1 ton of pellet from renewable wood. More specifically, the analysis has included the expenditures for energy, labour and space occupied by the plant. The costs related to the acquisition of the necessary quantity of wood to produce 1 ton of wood pellets have been neglected since such kind of biomass is still considered as waste and currently it doesn't possess any economic value. The energy costs have been calculated with reference to the consumption of each phase in the treatment of 1 ton of wood pellets and to the current price of the electric power. The expenditures accounted to the labour for each phase have been calculated through the accounted involvement of the personnel in the production of 1 ton of wood pellets and the hourly cost of the employed workers. The costs involved for the space occupied by the plant have been calculated dividing the monthly amount of real estate expenditures for the industrial site by the potential production of the plant in the same period, in terms of tons of wood pellets. Then, such expenditures have been split to calculate the amount accounted to each process step taking into consideration the ratio of the space occupied by the machinery utilized to perform the phases.

Thus, the expenditure values have been calculated through the following (3), (4), (5).

Energy expenditure = phase required energy for processing 1 ton of pellet X *electric power cost* (3)

Labour expenditure = employed labour hours for the phase X *hourly labour cost index* (4)

Space expenditure = ratio of the space occupation for the phase machinery X *monthly real estate expenditure / number of 1 ton batches of pellet potentially produced in a month* (5)

Table 6 shows the results of estimated expenditures for the exploited resources and the phases overall values

POV_j, consequently calculated through (2) and subsequently normalized in order to obtain a percentage score.

Phase	*POSj*	Energy	Labour	Space	*POVj*
A1	2,3	3,0	2,0	1,0	31,7%
A2	0,9	2,0	2,0	2,0	12,4%
A3	3,0	38,0	6,0	3,5	5,2%
A4	0,7	3,0	2,0	1,0	8,3%
A5	7,3	11,0	10,0	1,0	27,5%
A6	0,8	1,5	2,0	1,5	14,9%

Table 6: Overall value POV_j of each production phase, estimated as the ratio between the contribution to the customer perceived value (POSj) and the resources consumption. Energy, labour and space resources have been determined according to (3), (4) and (5) and are expressed in €/ton; in grey the most critical process phase.

4.5 Prioritizing the directions for improvement

As shown in Table 6, the dewatering task (A3) has the smallest *POV* index, thus it represents the most critical phase of the business process, since its contribution to the creation of the value of the product, compared with the other phases of the same manufacturing process, is not proportioned to its consumption of resources.

Similarly, the second trituration phase (A4) seems to present critical issues.

A more detailed analysis of the process, performed on the basis of the above mentioned results, reveals that some important limits of the production process of pellet starting from wood waste are due to technologies that are not able to treat, in an efficient way, biomass having a high moisture content.

In order to obtain pellet with a high energetic yield, the moisture content in the green biomass (approximately 50% in weight) must be drastically reduced. The technologies based on thermal dewatering use rotating or fluid bed furnaces that are fed by methane, oils, or a part of the raw biomass. This involves high fuel consumption, due to the meaningful amount of water that should be extracted. The efficiency of the dewatering phase could be strongly improved if the size of the biomass could be reduced at the inlet of the furnaces but unfortunately current systems for wood trituration are not able to treat biomass having a high moisture content. Moreover the pressing technologies used for the pelletizing of the sawdust are not able to dewater the biomass.

The analysis performed so far suggests improvements of dewatering and second trituration phases by developing convenient manufacturing technologies for wood pellet production. The goal is to obtain wood pellets capable to satisfy the CRs, using wood waste coming from forest and urban green maintenance. In such a way the pellet market demand could be totally satisfied thanks to a more rational exploitation of the available biomass resources.

5 DISCUSSION AND CONCLUSIONS

The analysis of the scientific and technical literature in the field of renewable energy confirms that the drying and the trituration of the woody biomass are critical phases in the production process of pellet starting from green wood. In [32, 33] it is clearly explained that the drying process based on thermal heating has a not negligible impact on both quality and production costs of wood pellet and new drying systems should be developed in order to make more efficient the pellet manufacturing process in terms of energy consumption and product characteristics delivered to the final customer. In [34] it is claimed that in wood manufacturing industry, drying is considered the most relevant matter determining problems in process controllability and high energy expenditures. Several studies have been carried out and several technologies have been introduced to improve this phase in wood industry, as it is summarized in [35]. Furthermore, previous researches performed by the authors aimed at identifying the constraints of the pellet production process in terms of throughput, has led to individuate the trituration and dewatering phases as process bottlenecks [36].

The aforementioned researches and several others, widely confirm the results obtained by the application of the proposed Process Value Analysis. Such evidence provides a positive feedback for the applicability of the proposed methodology for re-engineering activities of business process experiencing under capacities in satisfying the product market demand.

The proposed method allows the identification of the critical process phases on the basis of the evaluation of their impact in determining the customer perceived value of the product attributes. This evaluation also takes into account all the resources each phase involves in order to guarantee such attributes.

As stated in section 1 the Process Value Analysis has demonstrated its efficiency in business process re-engineering tasks mainly related to well established processes needing to preserve the competitiveness of the delivered products/services in a crowded marketplace. In this paper its applicability to another class of problems concerning under development processes not able to satisfy the market demand, whereas the customer requirements are described by a set of goal attributes to be performed in order to access the market. In this specific case the test has been carried for a business process with poor performances, which consequently don't allow the complete exploitation of both the available resources, and the market demand.

6 REFERENCES

[1] Borgianni Y., Cascini G., Rotini F., 2010, Process Value Analysis for Business process Re-engineering", Proceedings of IMeche Part B: J. Engineering Manufacture, 224: 305-327.

[2] Tripsas, M., 2007, Customer Preference Discontinuities: A Trigger for Radical Technological Change, Managerial and Decision Economics, 2-3: 79-97.

[3] Forrest, J., 2004, Evolution and Behavior of System Structure: Eight Perspectives for Examining Complex Issues, in Conference of the System Dynamics Society, Oxford, United Kingdom, July 25-29, 2004.

[4] Mory, E.H., Salisbury D.F., 1992, School restructuring: The critical element of total system design, in annual meeting of the American Educational Research Association, Washington, DC, United States of America, June 19-21, 1992.

[5] Kim, W.C., Mauborgne, R., 2005, Blue Ocean Strategy: How to Create Uncontested Market Space and Make Competition Irrelevant, Harvard Business School Press, Boston, United States of America.

[6] Lacroix, R.N., 2006, Business plan for a Modern and Efficient Business, 5th Entrepreneurship Workshop

at Harokopio University, Athens, Greece, December 5-6, 2006.

[7] Brockman, K., 2008, How to Perform a Feasibility Study and Market Analysis to Determine if an Ancillary Service Makes Sense, Orthopedic Clinics of North America, 39: 5-9.

[8] Mačikėnas, E., Makūnaitė, R., 2008, Applying Agent in Business Evaluation Systems, Information Technology And Control, 37: 101-105.

[9] Kim, W.C., Mauborgne, R., 2001, Knowing a winning business idea when you see one, Harvard Business Review, 78: 129-138.

[10] Kusiak, A., Tang, C.Y., 2006, Innovation in a Requirement Life-Cycle Framework, in Proceedings of the 5th International Symposium on Intelligent Manufacturing Systems, IMS'2006, Sakarya, Turkey, May 29-31, 2006.

[11] Hammer, M., Champy, J., 1993, Reengineering the Corporation: a Manifesto for business revolution, Harper Collins, New York, United States of America.

[12] Davenport, T.H., 1993, Process Innovation: Reengineering Work Through Information Technology, Harvard Business School Press, Boston, United States of America.

[13] Johansson, H.J., 1993, Business process reengineering: breakpoint strategies for market dominance, Wiley, New York, United States of America.

[14] Chan, K.K., Spedding, T.A., 2003, An integrated multidimensional process improvement methodology for manufacturing systems, Computer & Industrial Engineering, 44:673-693.

[15] Reijers, H.A., Liman Mansar, S., 2005, Best practices in business process redesign: an overview and qualitative evaluation of successful redesign heuristics, Omega, 33: 283-306.

[16] Cameron, N.S., Braiden P.M., 2004, Using business process re-engineering for the development of production efficiency in companies making engineered to order products, International Journal of Production Economics, 89: 261-273.

[17] Herron, C., Braiden, P.M., 2006, A methodology for developing sustainable quantifiable productivity improvement in manufacturing companies, International Journal of Production Economics, 104: 143-153.

[18] Kaplan, R.S., Norton, D.P., 1996, Using the Balanced Scorecard as a Strategic Management System, Harvard Business Review, Jan–Feb: 75-85.

[19] Voelpel, S.C., Leibold, M., Eckhoff, R.A., Davenport, T.H., 2006, The tyranny of the balanced scorecard in the innovation economy, Journal of Intellectual Capital, 7: 43-60.

[20] Ibusuki, U., Kaminski, P.C., 2007, Product development process with focus on value engineering and target-costing: A case study in an automotive company, International Journal of Production Economics, 105: 459-474.

[21] Holland, D., Kumar, S., 1995, Getting past the obstacles to successful reengineering, Business Horizons, 38: 79–85.

[22] Hall, G., Rosenthal, J., Wade, J., 1993, How to make reengineering really work, Harvard Business Review, Nov-Dec: 119–131.

[23] Mont, O.K., 2002, Clarifying the concept of product–service system, Journal of Cleaner Production, 10: 237–245.

[24] Kusiak, A., Larson, T.N., Wang, J., 1994, Reengineering of design and manufacturing processes, Computers and Industrial Engineering, 26: 521–536.

[25] Romero, F., Company, P., Agost, M.J., Vila, C., 2008, Activity modelling in a collaborative ceramic tile design chain: an enhanced IDEF0 approach, Research in Engineering Design, 19: 1-20.

[26] Kucharavy, D., De Guio, R., Gautier, L., Marrony, M., 2007, Problem mapping for the assessment of technological barriers in the framework of innovative design, in International Conference on Engineering Design, ICED'07, Paris, France, August 28-31, 2007.

[27] Miles, L.D., 1961, Techniques of Value Analysis and Engineering, McGraw-Hill, New York, United States of America.

[28] Altshuller, G.S., 1984, Creavity as an exact science. The Theory of Solution of Inventive Problems, Gordon & Breach Science Publishers, New York, United States of America.

[29] Souchkov, V., 2007, Breakthrough Thinking with TRIZ for Business and Management: An Overview, ICG Training & Consulting, Enschede, The Netherlands.

[30] Ko, E., Kingade, D., Brown, J.R., 2000, Impact of business type upon the adoption of quick response technologies – The apparel industry experience, International Journal of Operations & Production Management, 20: 1093-1111.

[31] Becattini N., Cascini G., Rotini F., 2009, Correlations between the evolution of contradictions and the law of ideality increase, in Proceedings of the 9th ETRIA TRIZ Future Conference (sponsored by CIRP), Timişoara, Romania, November 4-6, 2009.

[32] Andersson, E., Harvey, S., Berntsson, T., 2006, Energy efficient upgrading of biofuel integrated with a pulp mill, Energy, 31: 1384–1394.

[33] Wolf,A., Vidlund, A., Andersson, E., Energy-efficient pellet production in the forest industry—a study of obstacles and success factors, Biomass and Bioenergy, 30: 38–45.

[34] Valentino, G.A., Leija, L., Riera, E., Rodriguez, G., Gallego, J.A., 2002, Wood drying by using high power ultrasound and infrared radiation, in Proceedings of Forum Acousticum, Sevilla, Spain, September 16-20, 2002.

[35] Mujumdar, A.S., 2006, An overview of innovation in industrial drying: current status and R&D needs, Transport in Porous Media, 66: 3-18.

[36] Cascini, G., Rissone, P., Rotini, F., 2008, Business reengineering through integration of methods and tools for process innovation, Proceedings of IMechE Part B: J. Engineering Manufacture, 222: 1714-1725.