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Redesign of Supply Chain in Fashion Industry based on Strategic Engineering

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Abstract

This paper proposes the innovative approach of Strategic Engineering to Fashion Industry in order to redesign the Supply Chain of Medium Size Enterprises active in high quality Made in Italian women's footwear and how this innovative approach could support enhancements and improvements over multiple target functions. The paper introduces the approach and proposes the framework as example of how combining Modeling and Simulation, Artificial Intelligence and Data Analytics in closed loop with real data it could be possible to support Decision Makers in re-engineering processes and redesigning business models even in Small Medium Size Enterprises devoted to high quality production.

Keywords: Strategic Engineering, Modeling & Simulation, Fashion Industry, Supply Chain Management

1. Introduction

The Strategic Engineering is a new discipline emerged along last 6 years that combines the use of Artificial Intelligence (AI), Data Analytics, Modeling & Simulation (M&S) with real data obtained from Company Digitalization, IoT/IIoT (Internet of Things and Industrial IoT), sensor grids and heterogeneous networks in order to support decision making. The key point is to consider the use of AI as enabler of more sophisticated aspects in both a posteriori and a priori analysis [1]. The paper presents an example about how to apply this discipline to Fashion Industry considering that this sector has peculiar problems related to the high volatility of the products, high variability due to the high quality of man made activities and the difficulties in planning industrial processes over small quantities [2][3]. Due to these reasons the paper presents a case study about how to scale Strategic Engineering for Small, Medium Size Industries in Fashion Industry with special attention to man made in Italian women's footwear production [4]. The current opportunities provided by innovation and new approach in Fashion are very interesting [5][6][7].

2. Strategic Engineering

Indeed, nowadays Big Data are available due to general digitalization of Companies, Industries, Society and even people, this aspect is further reinforced by Industry 4.0 evolution making much more effective the potential provided by modern Data Analytics methodologies and computation power of cloud services, therefore it should be outlined the criticalities present in Data that are usually full of inconsistencies, errors, decoupled sets, missing values as well as information: in practice it could be correct to state that Big Data correspond usually to Big Mess, therefore IA could correct partially these elements by filtering, checking, elaborating the data and conduct advanced data fusion to extract valuable information [1].

However, Data Analytics, combined with AI, results very good for a posteriori analysis, but cannot predict future events respect crucial decisions and acts carried out by us or by our partners/antagonists or due to substantial changes on the general scenario a priori. Being based on data analysis of historical cases it is very hard to predict impact of decisions and changes not evolving progressively, while, even in these last cases, the Data Analytics identify the new trends by some latency due to the inertia of the whole data set to shift to the new behaviors.

Considering these elements, it results fundamental to couple a posteriori analysis with some other technique able to deal with a priori analysis and to forecast the consequences of our decisions and scenario changes: in this case the key methodology is obviously M&S, therefore also in this case the combination with AI elements allows to reproduce on future events the actions and reactions of the different players during a simulation.

Finally event the combination of a posteriori and a priori analysis don't allow to create a reliable Strategic Engineering Approach, but it is required to close the loop by adding some intelligent Solution (e.g., Machine Learning, ML) able to process the feedback from the field on the impacts of our decisions and to correct the Model tuning and the Simulation Settings in order to self adapt itself on real system and its own behaviors and reactions.

This is particularly interesting in Complex Industrial Processes such as a Supply Chain where it could be difficult to create a valid model and to have an effective planning system respect a dynamic market; from this point of view the use of Strategic Engineering Approach is very valuable and it was applied in the proposed case study.

3. Analyzing the Criticalities of High Quality Women's Footwear Man Made in Italy

The case of Women's Footwear Man made in Italy is quite interesting for the complexity due to several elements of its industrial processes and supply chain [8]. First of all, as in all Fashion Industry, it is important to state that products are affected by high volatility, indeed the fashion items usually expire after a single season and don't provide time series and historical data to conduct analysis on supplier performance and/or to support demand forecasts; the problem could be partially solved by adopting meta categories that correlate similar products among different seasons, therefore this approach is quite sophisticated considering that these meta classes should be multidimensional considering both style, customer target, sale channels, geographic regions, expert forecasts and other elements that are not so easy to fuse together (e.g. the expected success of a classic line on North America distributed over an internet marketplace within luxury level); the authors have experience in this application and it should be considered important for obtaining valuable information in this sector [9]. In addition to these aspects, it should be considered the high variability due to the specific production approach that is often based on high quality handcraft activities [10]; indeed, in this sector the man made activities produce very high value by workers that are almost artisans and introduces stochastic factors in productions rates as well as difficulties in estimating efficiency and effectiveness over new models or introducing new suppliers for outsourcing. Another important element is the complexity of planning the industrial processes over small quantities as usually happen for Small & Medium size Enterprises (SME) dealing with high quality man Made in Italy that are characterized by low volumes [11][12]; these companies in Fashion are the core of Italian Producers and produce in Fashion both directly or serving as suppliers for major griffes; in the sector of women's footwear made in Italy there is a predominance of the direct production and sales with great attention to the new opportunities provided by internet marketplaces that require a complete redesign of the Business Model as well as consequent adaptation of Supply Chain and Production Planning [13]. It should be even consider the constraints in this sector generated by the fact that the SME orders to crucial suppliers (e.g. tanneries for leather) collide with priorities given to major manufacturer that place much bigger orders (e.g. small quantities in leather orders to tannery

industries respect demand of others players or major griffes). All these elements are critical to be able to properly redesign the Supply Chain and identify best solution to increase flexibility and capability to react to new promotional campaign over Internet Marketplace keeping the very high quality standards and the foundations of the Made in Italy that represent by itself one of major Brands worldwide and a big added value for our SMEs [14][15]. These are obviously very good conditions to apply Strategic Engineering to redesign the Processes as well as the whole Supply Chain even in this small Companies

4. Improving the Processes and Redesigning Supply Chain Management

Usual main objectives of the Fashion Sector are to maintain very high quality standards with a reduced costs of processes and maximization of their effectiveness and flexibility [8]. In facts, these elements allow to increase the Profits and the Competitiveness of the Companies in general and SMEs, in particular. These improvements should reinforced nowadays by diffusion and adoption of new technologies (e.g. Industry 4.0 work stations, company digitalization, use of AI, M&S) that represent key factors for optimization; therefore, in many applications, the use of new Solutions and Technologies is still limited due to many reasons including the limited size of the companies that don't allow to activate middle/long term innovative projects; in the proposed case thanks to the support of a Italian Region and the open mind of key Companies it was possible to activate a research and an experimentation on the field about how to use Strategic Engineering in this sector.

In facts, one critical problem is that sometimes a supply chain could turn uncompetitive due to market evolution and it becomes essential to analyze all the processes to identify how to improve it and return to be effective respect competitors and customer evolution (e.g., new sale channels, internet marketplaces). However, the Supply Chains are very specific for each case, characterized by many elements and factors, influenced by uncertainty, variability and dynamics that create a rather complex system that normally requires the adoption of Innovative Techniques for the Identification of new winning strategies through reengineering, reorganization and revision of the architecture and management. Typically, many aspects are involved in this business, including logistics, customer relations, removing bottlenecks, and rethinking downtime; it is evident how Strategic Engineering using extensively M&S could turn to be crucial to address these issues.

Indeed, Simulation is the key approach to reproduce the Production Processes, internal ones as well as outsourcing, and to compare all the main differences among alternative new solutions to finalize quickly and effectively the redesign of the Supply Chain that could be virtually tested by this approach.

The focus of the simulation system tailored for this case study was concentrated on the women footwear supply chain by exploiting the synergy with the research, experiences and analyzes developed by the PUSL which defined the objectives of the new Supply Chain Management (SCM); this new approach was mainly aimed at improving the entire Supply Chain, reducing production times, weakness respect major industrial suppliers (e.g. tannery industrial providers) as well as costs; obviously a major attention was devoted to improve KPIs (Key Performance Indicators) by creating a Model able to virtually test strategies and solutions for decision makers and to be re-tuned dynamically by Strategic Engineering approach thanks to the analysis of the effective performance achieved on the field after the implementation of the SCM changes.

5. Women's Footwear Supply Chain Management and Production processes within SMEs

In this field, production starts at the beginning of the season, when the design office creates the new shoe models to be produced, so it is necessary to create Simulation Models able to consider this critical phase and how it could evolve based on different promotional activities going not through fairs and exhibitions, but developing over internet marketplace campaigns.

In facts, traditionally, the orders are generated by the Customers' Requests on the basis of the appreciation at the Fairs on Models developed by the design office. However, many variations of the main models are prepared, so the customer orders result really tailor-made. In production, this implies a strong variability between orders, especially as regards materials and specific processes (e.g., buckles) as proposed in following figure.

Fig.1. Supply Chain Drivers

In facts, the SMEs plan production on the basis of orders, in particular the Plan defines the times and quantities of Components and Raw Materials to be ordered from suppliers and the agreements with them for the activation of the Supply Chain [8]; the main steps to reproduce the Supply Chain are proposed in following figure and include:

- Orders for raw materials and components
- Treatment of Materials with specific processes: each shoe is treated according to the needs of the Customer, often with Outsourcing and Third Parties
- Assembling the shoe, when all materials and components are ready
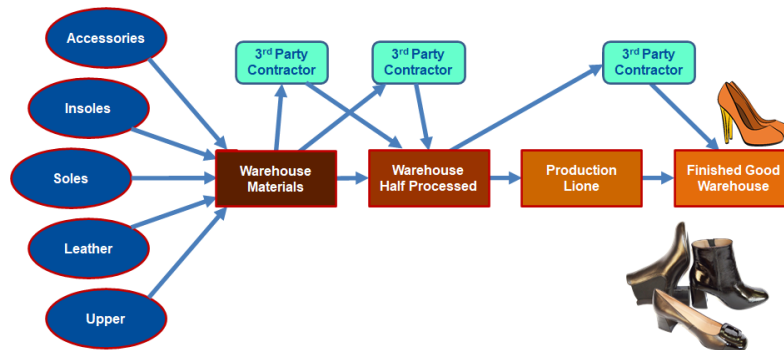- Quality control and testing: before delivery

Fig.2. Supply Chain Drivers

The flows of materials and components are divided into different phases to finalize the finished product.

The phases are modeled to reproduce the Supply Chain and generated based on data available on company database; in fact the production process is often different for the different types of shoes, moreover, further requests may be requested by the customer. Useful historical information is divided by orders and meta-products, from which information on the production cycle of each group of shoes is extracted (e.g., arrival of materials, delivery of batches, dead times). This information is compared with information on each particular type of shoe, in relation to the explosion of the product in terms of different requirements for raw materials and accessories. Mainly the decision-making variables are linked to the "when" and "how much" to order: many suppliers are involved, with different timing and minimum order quantities that could be dynamically updated based on data collected on the company information systems. In facts, the flow of information through the different actors in the chain is not always efficient and, if poorly planned, delays and misalignments could occur among serial and parallel activities.

6. Women's Footwear Supply Chain Management Simulator

On the basis of these considerations, the conceptual model of the proposed Simulator was created allowing to consider the status quo of Production in operational terms, as well as to analyze new Configurations [14]; this approach enabled decision makers to be able to use the simulator to evaluate results and performance to identify the best solutions and select it among the many possible alternatives. The model has been developed as components of a Stochastic Discrete Event Simulator agent Driven dynamically connected with real data to set times and process directions among different production elements, suppliers and outsource policies. The Simulator uses the Monte Carlo technique as part of the Strategic Engineering Architecture [1].
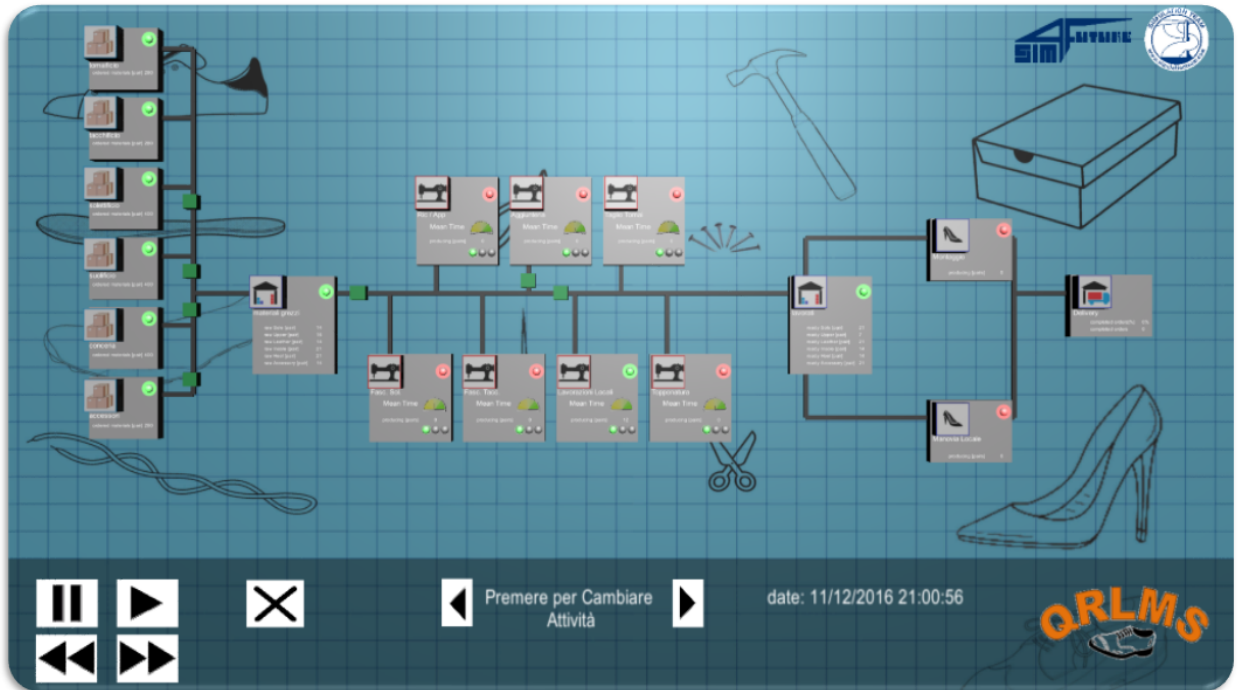
Fig.3 Simulator Dynamic Interface

The Model created allows us to consider the status quo of Production in terms of operations, as well as the analysis of new Configurations; so Decision Makers are enabled to use the simulator to evaluate results and performance to identify the best solutions and select an alternative [8]. In this case we don't introduced a very Sophisticated AI solution considering this project was dealing with a demonstration, therefore, the authors decided to consider use of Intelligent Agents for the management of the basic choices to be performed automatically during the simulation. In facts, intelligent agents (IA) are useful in Simulation to reproduce specific elements with particular behaviors; in facts, the Agents are entities in the simulation environment that perceive the situation, apply decision making, and interact with the environment and with each other. Agents are useful for reproducing complex systems and allow you to represent the different actors involved in the supply chain, such as contractors, warehouse control logic and assembly lines. In our case, the IAs direct each order based on the principia suggested by new SCM Policies and real data from the field about the actual efficiency of operational procedures. The historical data on the arrivals of Suppliers and Materials/Components are acquired from the order lists. It must be said that this data could include errors generated within the ICT systems, so data filtering is required to avoid errors and missing data. This is especially true for dates, as there may be discrepancies between delivery and production dates. Subsequently, the data are merged with respect to the production processes, so the developed Model is able to generate correct and consistent information by applying the necessary filters and processing. During the Monte Carlo simulation, the model uses statistical distribution based on historical data to perform each different experiment. Alternatively, it is possible to run a status quo simulation as reference and to plot the path based only on existing data, while it is possible to create other data set to develop and test alternatives. The development and validation of the model was based on visit to production facilities of SMEs and evaluation of M&S for finalizing the VV&T (Verification, Validation and Testing) of the whole solution [15]. The developed simulator resulted very efficient computationally, thanks to his Stochastic Discrete Events paradigm and is implemented in C#; in addition, the simulator allows to be run within a graphical user interface that proposes the different boundary conditions and the dynamic animation of the order processing along the Supply Chain as proposed in previous figure. The graphic interface allows to quickly and intuitively understand the scenario evolution; this representation is dynamically and present a synthetic and effective summary of the KPIs, while, obviously, all the detailed results are available on the output files.

7. Conclusions

The Simulation and Data Analysis Models are now available as a decision support solution in supply chain optimization. The models analyze real data and the simulator allows the Company Decision Makers to test strategies as well as new configurations and sale channels a priori, just virtually.

The Simulator and the Data Analysis System allow to improve Competitiveness by speeding up the planning of operations, reducing delays due to planning and saving on production costs; this is crucial to enable the new Business Models relying on internet marketplaces.

It is important to outline that this was a preliminary research project devoted to create already a valuable asset for future developments, but it was mostly devoted to diffuse in the SMEs the knowledge of potential of these new technologies; based on the very positive feedback collected by potential users and considering the interest of the Research Sponsors, currently the authors are working toward development of further researches in this area, even considering to move from the research phase to the creation of an industrial service thanks to the synergy between the University that carried out the R&D Project and the Spinoff Company that implemented the Architecture and Simulation Model.

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