An algorithm for supply chain integration based on OTSM-TRIZ

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Abstract

In the paper an operative algorithm is described that guides decision makers in selecting the best supply chain integration strategy to follow when problems occur. The aim of the algorithm, inspired by the Theory of Inventive Problem Solving, and specifically by the body of knowledge of its recent evolution (OTSM-TRIZ) is to address managerial problems following a structured reasoning approach: a five steps procedure has been formulated to systematically structure the problem context, generate solutions and assess the potential effects of each solution. A case study has been developed, to test the algorithm effectiveness and usability, in collaboration with the Chilean company ARAUCO S.A., one of the major forestry companies in the world. The results demonstrate the efficacy of the algorithm to support decision makers in correctly implementing the identified problem solutions within the company development process and organizational structure.

Keywords: Supply chain integration; OTSM-TRIZ;

1. Introduction

Due to continuous changes in company manufacturing strategy (Cagliano et al, 2005) the supply chain role and the way it is integrated in the product development process assume various connotations with the intent of providing maximum value to end-customers. Both vertical and horizontal integration can...
occur between a company and its external network (Rudberg and Olhager, 2003) while selecting the correct integration strategy is not a simple task to perform; indeed, improperly introduced or ill-conceived decisions can cause considerable losses in terms of longer time to market and missed business opportunities: the risk connected to these decisions is always latent (Thonemann and Bradley, 2002) Models are available in literature to help decision makers predicting these managerial risks and recognizing obstacles, so as to prevent or at least mitigate their impact. However, their applicability in specific industrial context is not always feasible and effective: they do not consider firms’ distinctive features and, for that reason, there are many different models in the literature (Braunschside and Suresh, 2009), which are fundamental for correctly identifying critical areas of integration needed to guarantee supply chain effectiveness. The research activity described in this paper aims at addressing these managerial issues designing and following a more structured approach. To reach this purpose an algorithm has been elaborated to guide the selection of the best supply chain integration strategy to follow. The algorithm generation has been inspired by the Theory of Inventive Problem Solving (Altshuller, 1984), better known as TRIZ, and specifically, its recent evolution, indicated with the acronym OTSM-TRIZ, whose aim is to provide instruments to increase the efficiency of problem solving sessions in case of non-typical and complex interdisciplinary problems (Cavallucci and Khomenko, 2007). The research activity has been structured following a two-step approach. In the first stage efforts have been spent analysing in details the complexity of the integration process, which demands variability and high investment risks as well as requires responsive, flexible and adaptable supply chain. In the second stage, an algorithm has been elaborated to guide managers in the decisional process through a map of such variable and risky scenarios: starting from OTSM-TRIZ Body of Knowledge, a five steps procedure has been formulated to systematically structure the problem context, generate solutions and assess the potential effects of each solution. The research activity has been carried out in collaboration with the Chilean company ARAUCO S.A (www.arauco.cl), one of the major forestry companies in the world. Indeed, considering the organizational and supply chain strategy changes occurred in the last years at its Trupan-Cholguan production plant, as well as, its new corporate vision focused to extend the company to international markets and guide medium and long term growth, the Chilean company has been seen as a significant and opportune example to study company internal organizational and decisional procedures and assess the effectiveness and applicability of authors’ algorithm into a real industrial environment. Specifically, operation and human resource managers have been actively involved in the case study development since the company priorities were to evaluate and map how supply chain related decisions can affect the company strategic business plan, its internal processes and the capability of the company to meet customer expectations.

Section 2 overviews supply chain integration problems, as well as the scientific base that has inspired authors’ research, while section 3 presents the proposed algorithm. Section 4 discusses the developed case study to validate the algorithm. Finally, the paper ends with a brief summary of conclusions and possible future research scenarios.

2. Literature review

2.1. Solving supply chain integration problems: the importance of models

A supply chain can be described as a system made up of organizations, people, technology, activities, information and resources involved in moving a product or service from the supplier to the customer. Supply chain activities transform natural resources, raw materials and components into a finished product that is delivered to the end customer. Purchasing, logistics and business topics have been deeply
investigated by the research community (La Londe and Masters, 1994) (New, 1997) (Tan et al., 1998): for instance, more than thirty decision methods have been defined in literature for supplier selection (De Boer et al., 2001). Research findings demonstrate how companies have to move relatively easily from one manufacturing strategy to another in order to satisfy continuously changing market and organizational targets (Cagliano et al., 2005) and that, in performing those shifts, a correct integration of the various stakeholders (i.e. suppliers, manufacturers and customers) is required (Froblich and Westbrook, 2001): manufacturing strategy needs to be aligned across the supply chain and not just inside organizations. The first cross-industry framework defined in literature for evaluating and improving enterprise-wide supply-chain performance and management has been the well-known Supply-Chain Operations Reference model (SCOR®) (Stewart, 1997), which has put emphasis on measuring supply chain performances in terms of reliability, cost, responsiveness and flexibility.

To solve supply chain related problems several tools and models are available in literature and efforts have been also spent to classify them (De Boer et al., 2001)(Tsoukiás, 2008) (Beamon, 1998), demonstrating that to be more comprehensive, these models should also include BOM constraints, stochastic factors, and qualitative aspects that are fundamental within a global environment (Vidal and Goetschalckx, 1997). Tools can be divided in qualitative and quantitative: while the firsts support analysts during the problem and criteria formulation phases, the seconds help decision makers to select the most promising problem solution according to the defined company goals and criteria. Together with tools, various modelling strategies are also available to analyse supply chain behaviours. According to Beamon, multi-stage supply chain models can be clustered into four groups: deterministic, stochastic, economic and simulation-based. Deterministic analytical models can be applied if problem variables and boundary conditions are known (Williams, 1983) (Cohen and Lee, 1988); on the contrary, in stochastic models, probability distributions are necessary when at least one of those variables is unknown. Economic models follow the game-theoretic framework for modelling relationships within the supply chain (Christy and Grout, 1994), while simulation based ones offer a sort of virtual environment where to evaluate, compare and cost the effects of different business and integration strategies, suggesting also how improvements might be made (Wikner, Towill and Naim, 1991).

Overall, despite of the efforts spent by the research community to model and solve the problems that occur when companies try to update their supply chain integration strategies, a more structured decisional technique is still lacking: it should contemporary act as a model and as a tool, since it should aid both in the analysis and in the redesign phase of the supply chain, keeping the problem traceable through the mapping of the reasoning and decisional path followed to overcome problems. Indeed, it should not only suggest the most promising solutions according to a list of criteria, but it should also highlight to decision makers the consequences of their decisions: inadequate assessment and planning of the solution implementation can lead to costly knock-on effects across the entire product development process.

2.2 From problem analysis to problem resolution: OTSM-TRIZ potentials

TRIZ* is a methodology created by Genrich Altshuller with the purpose of improving the efficiency of problem-solving activities when addressing non-typical, namely inventive, problems. TRIZ logic and tools are rooted in the observation that the evolution of technical systems follows repeatable patterns. Thus, a problem solver should focus on identifying those patterns so as to effectively and systematically narrow the area of analysis and hence the search for new or better “non-typical” solutions. Since it is

* Teoriya Resheniya Izobreatatel skikh Zadatch. Russian language
impossible to provide a comprehensive description of the TRIZ theory in a paper section, the following paragraphs will discuss the elements the authors have taken as the basis for this study.

The architecture of TRIZ is based on three postulates: the existence of objective “laws” describing the evolution of technical systems; the dynamics of contradiction as the basic mechanism behind systems evolution; the exploitation of all the available resources characterizing a specific situation.

Altshuller discovered systems evolve by overcoming conflicts, in TRIZ terms contradictions, rather than accepting trade-off solutions; similar contradictions recur across different industrial fields, and can be addressed by following the same solution paths. Classical TRIZ distinguishes three levels of formalization of the contradictions: administrative, technical and physical. A technical contradiction takes place when two evaluation parameters (EPs), of the system under investigation, conflict with each other, i.e. the improvement in the value of one evaluation parameter worsens the value of the other. The physical contradiction is the underlying conflict between two opposite values of a certain design variable, each value capable to improve one of the EPs of the technical contradictions mentioned above, but thus resulting in a worsening effect of the other EP.

TRIZ provides a set of heuristics to overcome contradictions by leveraging available resources classified into five categories: time, space, energy, information and materials; some authors have proposed more structured resources classifications as in (Becattini et al., 2011), also considering managerial-based resources (Mueller, 2005). Both the analysis and the solution synthesis phases are guided with a system-thinking vision, through the prescriptive directions of the System Operator Model, a sort of template for looking at the problem at different levels (i.e. components, subsystems, system, and super-systems) and at different time frames. In this paper, an original reinterpretation of the System Operator is suggested in section 3.

The generation of solutions is further guided by “inventive principles” and generalized “standard solutions”. Among the others, it is here useful to mention the Four Separation Principles, which help addressing physical contradictions:

- **Separation in space.** The contradictory requirements or functions of a system can be separated into different spatial regions, e.g. according to the sub-systems distribution, so that these subsystems can perform their own functions without negatively affect the others (e.g. hospitals are often separated into different departments and into different space zones (ophthalmologist, pediatric, etc.) or supermarket create different place for food and chemical products).

- **Separation in time.** The contradictory requirements of a system can be separated in different time intervals, so that these requirements or functions can be met or operate at different time schedules without negatively affect the others (e.g. in case of variable manufacturing cycles, a company can temporarily hire more people; cinemas offer discounts in different periods to balance customer demands).

- **Separation between the whole and its parts.** The contradictory requirements can be overcome by distinguishing the property of the whole system with respect to its subsystems (e.g. a company with a large and diversed network of very specialized suppliers is flexible as a general-purpose manufacturer, but professional as an expert in the field.).

- **Separation Upon Conditions.** The contradictory requirements can be separated changing the condition settings (e.g. a Mexican restaurant cooking the same dish with different levels of “hotness” upon condition of customer taste.)

The implementation of the Four Separation Principles does not represent the only available strategy, within TRIZ, to support the solution generation phase; the fact is that in developing the case study, these principles have been found to have high potentialities for solving supply chain problems characterized by a strong managerial focus.
2.3 The OTSM Problem Flow Network approach: how to identify and map contradictions.

OTSM is an evolution of classical TRIZ: originally proposed by Nikholai Khomenko, it aims at managing complex interdisciplinary problems (Cavallucci and Khomenko, 2007). According to this purpose additional instruments and models have been added to the classical TRIZ and, specifically, a complete new procedure based on the concept of networks, namely the Problem Flow Network (PFN). In the frame of OTSM-TRIZ a complex problem can be viewed as a network of several underlying simpler problems. At the root of the network of problems reside the conflicting requirements for the design variables of the overall system and of the constituting element, i.e. a network of contradictions can be mapped to the network of problems. The complexity further increases when various knowledge domains, as well as technical-social-economic-environmental issues, are involved.

OTSM-TRIZ toolkit includes models to represent and manage those networks. The so-called Network of Problems (NoP) (Khomenko et al., 2007) is a graph where nodes represent either (Sub-)Problems (Pb) or Partial Solutions (PS). Their connection provides a hierarchical structure of the complex problem situation together with various alternatives to solve or mitigate Sub-Problems. The strength of the NoP graph is to offer the possibility to contemporary generate and visualize several problem scenarios. The process to map the NoP into a Network of Contradictions (Baldussu et al, 2011) requires distinguishing two different classes of parameters: Control Parameters (CPs) that can be leveraged by decision makers in order to obtain a specific outcome, i.e. to implement a specific partial solution, and the Evaluation Parameters (EPs), that allow to assesses the positive or negative implications of decision makers’ choice. Figure 1 shows an elementary contradiction, i.e. a building block for the construction of a Network of Contradictions.

![Elementary model of a contradiction according to the OTSM-TRIZ formalism.](image)

3. The supply chain integration as a complex problem: an OSTM-TRIZ based algorithm

As discussed in section 2.1, the existing techniques to manage the complexity of supply chain management miss to properly map all the problems and the difficulties that a strategic decision implies. The original contribution of this paper consists in an original procedure to guide supply chain configuration problems with an OTSM-TRIZ logic.

The 5-steps approach can be considered as a sort of operative algorithm that describes all the specific actions to perform in order to correctly manage problem complexity.

**STEP 1 - Problem context formulation.** Decision makers have to focalize the AS-IS situation, and its various levels of analysis that, according to companies’ current practices, one can identify in the following three levels: strategic planning, processes and customer satisfaction. (Stewart, 1997) (Stephens, 2001). The SCOR model can be used to map the current supply chain integration strategy. During that first step, the tasks to perform are then the following:
1. Draw or use the company supply chain SCOR diagram, specifically the process elements (3rd level of the SCOR diagram) that provide greater insight into the operation of the supply chain.

2. Select the specific stage in the SCOR diagram where to start the analysis: it is the stage where the specific problem has occurred.

3. Build the System Operator 3D model (Figure 2) originally proposed in this paper, and constituted by the following axes:
   - x-axis: scale of time (the past, present and future of the supply chain)
   - y-axis: scale of levels (the previously defined 3 levels of the company strategic vision).
   - z-axis: scale of supply chain stages according to the SCOR representation (the stage where the specific problem has occurred should be put in the middle).

4. Complete the System Operator according to the boxes definition for each selected SCOR stage.

Figure 2. The 3D system operators: the 3 levels of analysis; the time; the SCOR process stages.

**STEP 2- Problem analysis: resources classification.** This second step requires putting effort on correctly identifying the distribution and availability of company’s resources, within and outside it, according to the various levels of analysis defined in step 1 (y-axis of the System Operator). That TRIZ-based classification of resources represents the basis for resolving the contradictions that will appear in the next stages:

- **Material:** what composed a system and its surroundings. Readily available resources include raw materials or semi-finished products, as well as waste or absence of a substance; *material manufacturing*, it’s a mix of general and specific elements of the company production plant equipments (i.e. cutting/press machines) as well as the manufactured by-products.

- **Energy:** any kind of energy inside or around a system (i.e. gravitation, light or electromagnetic radiation); *energy human resource*, when humans are just contributing with their force and motion.

- **Information:** any perceptible information about the system (i.e. properties of the system and their changes, temporary information, information flow); *informatics human resource*, when humans contribute with their knowhow and creativity).
- **Time**: any kind of time including intervals (i.e. preliminary work, scheduled work flow, parallel processes, pauses, temporary actions).
- **Space**: any free/unused space in a system or in its environment, (i.e. the spare wheel space in a car).

**STEP 3- Problem representation: building the NoP.** The third stage of the approach is focused on recreating the various problem scenarios, modelling the NoC. Considering the complexity of supply chain integration related problems, several partial solutions will appear. Furthermore, in this stage, the resource classification defined in step 2 will be used to correctly select the evaluation parameters that will be used to measure the effectiveness of both partial and final solutions. The main actions to be performed during this stage are then the following:

1. Identify the specific problem (or the need for changes) occurred in the supply chain integration strategy, taking into account the third level of the SCOR diagram.
2. Generate a list of sub-problems and partial solutions and build the NoP by linking them logically.
   a. If the decision maker recognizes a new problem he/she has to generate a partial solution that can overcome the new problem.
   b. If the decision maker comes out with a partial solution he/she should reflect to identify new problems that might appear when implementing that new solution.
3. For each proposed partial solution appearing in the NoP, identify the CP and EP.

**STEP 4- Problem solution: contradictions resolution and consequences analysis.** The purpose of the fourth step is to address and resolve the contradictions emerging from the PFN according to the four separation principles briefly introduced in section 2.2. In Figure 3 is reported the reasoning workflow that decision makers should follow to correctly solve the occurred contradictions. That workflow has been designed to help non-TRIZ experts to correctly perform such a fundamental step.

**STEP 5 - Solution evaluation: assessment of the changes to be implemented in the supply chain integration strategy.** In this last stage, the evaluation parameters defined in stage 3 will be used to rank and select the solutions according to the specific context situation: the evaluation parameters can then be considered as the company key performance indexes to measure the solution expected success. It could be also of interest for decision makers to assess the time-dependency of the selected solutions.

![Diagram](figure3.png)

Figure 3. The decision makers’ reasoning workflow: an example of how to correctly address problem contradictions.
4. A case study from the forestry industry: the Chilean company ARAUCO S.A.

In this section the authors attempt to demonstrate the effectiveness of the proposed algorithm by discussing its application within the decisional process of a Chilean multinational company, ARAUCO S.A., worldwide recognized as one of the leaders in the development of sustainable forest products. ARAUCO’s is now focusing its attention not only on satisfying its customers, but also on correctly balancing the company’s needs with those of its employees and the environment† as well. This is the starting point that has stimulated the company to introduce in the last years new organizational strategies. The case study discussed in this section is part of a research project, between Federico Santa Maria University and ARAUCO S.A., aimed at improving the problem solving skills regarding supply chain related managerial decisions of more than 150 employees. Specifically, the company experts involved are all working in the Trupan-Cholguan production plant, which has been subjected to major organizational changes according to the company strategic vision. The production capacity of that plant is guaranteed by 3 lines, which act in parallel. The problem addresses in the case study derives from the necessity to modify the wood panels cutting phase of the line 3 since it is currently representing a bottleneck.

STEP 1- Problem context formulation.

1. A simplified view of the company supply chain SCOR diagram is reported in Figure 4. As shown in the picture, the wood, which represents the raw material, is initially shredded and then mixed with adhesives. The resulting mixture is pressed so as to create panels with a specific thickness. Then, they are dried, classified in terms of specific quality indexes and finally cut at the exact dimensions. Finally, the cut panels are submitted to a new quality control analysis before the packaging phase.

Figure 4. System Operator in 3D and the simplified SCOR model of the ARAUCO’s manufacturing process.

† www.arauco.cl
2. The process stage to analyze is the cutting phase.
3. The 3D System Operator is built (Figure 4) taking into account the different level of the analysis (customer, process, strategic planning), as well as the process stages (panels quality control check, panels cutting, cut panels quality control check);
4. The system Operator elements are defined in details (Table 1) in order to state the boundaries of the analysis. In the current situation the manufacturing line has a semi-automatic machine which hinders the production process. The desired conditions, that will have to be reached in the “future” is the replacement of that machine with a new one able to automatically perform both the cutting phase, as well as the quality control one. That change should be performed because a new company vision has to be fulfilled, in order to “guarantee a sustainable development of forest products” and due to “higher levels of quality regulations”.

Table 1. The elements of the 3D system operator.

<table>
<thead>
<tr>
<th>z-axis</th>
<th>x-axis (Past)</th>
<th>x-axis (Present)</th>
<th>x-axis (Future)</th>
<th>y-axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>Increase company technological innovation level, competitiveness and decrease environmental impact.</td>
<td>To guarantee a sustainable development of forest products.</td>
<td>Strategy Planning</td>
<td></td>
</tr>
<tr>
<td>Panel quality control check (only visual)</td>
<td>Panel quality control check (semi-automatic).</td>
<td>Automatic quality control check using lasers.</td>
<td>Process</td>
<td></td>
</tr>
<tr>
<td>Strong focus in national customers</td>
<td>Strong focus in national customers and in selected international customers</td>
<td>Worldwide products with high quality standards. The environmental impact reduction is a must.</td>
<td>Customers</td>
<td></td>
</tr>
</tbody>
</table>

**STEP 2 – Problem analysis: resources classification**

The resources analysis is designed to identify the lists of elements or sources available within the company. Both “classical” resources as well as managerial ones have been considered (Table 2).
Table 2. The resource classification.

<table>
<thead>
<tr>
<th>Resource type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Wood, Water, Steam, wood chips, waste of wood.</td>
</tr>
<tr>
<td>Material Manufacturing</td>
<td>Cutting machine, panel of woods without correct measure, air extractors, cut panels, laser vision.</td>
</tr>
<tr>
<td>Energy</td>
<td>Electrical energy produced by the biomass plant owned by the company.</td>
</tr>
<tr>
<td>Energy human resource</td>
<td>Semi-automatic cutting machine</td>
</tr>
<tr>
<td>Information</td>
<td>Number of panels per day, number of stops per day, panel size, toneless of production.</td>
</tr>
<tr>
<td>Information human resource</td>
<td>Workers’ skills.</td>
</tr>
<tr>
<td>Time</td>
<td>Time in storage, time of cutting, time for quality control and dimensions check, time for maintenances, equipment starting-time, time required for new machine installation.</td>
</tr>
<tr>
<td>Space</td>
<td>Panels warehouses, operation area, space around the company production plant.</td>
</tr>
</tbody>
</table>

STEP 3 – Problem representation: building the Problem Flow Network.

1. The initial problem analyzed in this case study is the necessity to substitute the cutting machine installed in the line 3 of the production plant (Pb1).

2. Starting from that specific problem, the company experts have then identified the list of possible problems that could occur, as reported in Figure 5. A hierarchical graph is used to highlight how these sub-problems are correlated. The graph visually represents the problem situation and the possible paths to follow during the decisional process. Three main problems emerge as more relevant to investigate: the effects on the production capacity (Pb2); the effects in terms of customer satisfaction, which depends on the panels’ final quality (Pb3) and the potential impact on the company organizational structure (Pb4). Specifically, these three problems have emerged from interviews with the company managers (operational and human resources) involved in the case study.

![Figure 5. The case study network of problems: the cut machine replacement.](image-url)
3. Starting from the NoP, at least one EP can be identified for each problem and at least the variation of one design variable (CP) should characterize each partial solution (Figure 6).

Figure 6. The Network of Contradictions and how they are linked.

**STEP 4 – Problem solution: contradictions resolution and consequences analysis**

Starting from the network of contradictions (Figure 6) the three separation principles can be applied to generate solutions (Table 3). In this specific case, only separations in time and space have been proven to be effective ways to overcome the identified contradictions.
Table 3. How the separation principles have been applied to overcome contradictions.

<table>
<thead>
<tr>
<th>Contradiction (CP and EP)</th>
<th>Separation Principles</th>
<th>Generated solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP6: Flexibility of the company.</td>
<td></td>
<td>The change should be performed when the product demand is low (i.e. the winter period for the U.S market).</td>
</tr>
<tr>
<td>EP2: Line 3 production capacity lost</td>
<td>Separation in time</td>
<td></td>
</tr>
<tr>
<td>CP2: Time to perform replacement.</td>
<td>Separation in Space</td>
<td>Since the company plant has a large available space, the installation of the new machine can be performed in parallel while keeping going on the line 3 activity.</td>
</tr>
<tr>
<td>EP5: Line 1 and 2 production capacity.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP3: The number of people employed within the company.</td>
<td>Separation in time</td>
<td>The new cutting machine requires a new employee with high technical skills. The company can contract a new worker that will follow a 3 months trainee period before starting using the new machine.</td>
</tr>
<tr>
<td>EP4: Time find a new operator.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EP7.2: New machine operator cost</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4. The use of evaluation parameters to verify the effects of the new strategy implementation.

<table>
<thead>
<tr>
<th>The identified problems</th>
<th>Evaluation Parameters</th>
<th>Units</th>
<th>Company Data</th>
<th>Effects.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb2 How to guarantee the planned production capacity?</td>
<td>Line 3 production capacity lost (EP2)</td>
<td>m³/year</td>
<td>60.000</td>
<td>The company lost 3 day of operation time</td>
</tr>
<tr>
<td>Pb3 Are customers’ requests satisfied?</td>
<td>Number of new contracts (EP3)</td>
<td>Number</td>
<td>No information is available</td>
<td>The company production increase by about 2 ± 3.4%</td>
</tr>
<tr>
<td>Pb4 Is it necessary to find a new operator able to manage the new machine?</td>
<td>Time (EP4)</td>
<td>Months</td>
<td>4</td>
<td>The company contracted a new operator 3 months before the change.</td>
</tr>
<tr>
<td>Pb5 The production capacity of line 1 and 2 can exceed the planned value</td>
<td>Line 1 and 2 production capacity (EP5)</td>
<td>m³/year</td>
<td>500.000**</td>
<td>Not necessary with the integration of the new person and increase level of production.</td>
</tr>
<tr>
<td>Pb7 Costs of operation</td>
<td>Costs of human resources (EP7.1)</td>
<td>US/operator</td>
<td>10 US/h</td>
<td>The employee has been relocated in the same plant</td>
</tr>
<tr>
<td></td>
<td>New machine operator cost (EP7.2)</td>
<td>US/operator</td>
<td>15 US/h</td>
<td>50% more but the production has increased. *</td>
</tr>
<tr>
<td>Pb8 The operator need time to learn how to correctly manage the new machine.</td>
<td>Training time. (EP8)</td>
<td>Months</td>
<td>4</td>
<td>3 months</td>
</tr>
<tr>
<td>Pb9 The new operator has to be integrated into the company culture</td>
<td>Integration time (EP5)</td>
<td>Months</td>
<td>2</td>
<td>3 months</td>
</tr>
</tbody>
</table>

*the manufacturing process has 3 turns for the operation: the company contracted 2 new operators before the change while the third operator was contracted one month before the change.  
** The high difference in the production volume, between line 3 and lines 1-2, depends on the technological level of the line: the level of lines 1-2 is higher than line 3.

In Figure 6, two distinct situations can be appreciated: one is focused to keep under control the production volume while the other describes what could happen if the company would decide to replace the current operator. Both these two situations present a high number of contradictions; those contradictions can be used to help decision makers to understand the consequences of their decisions when planning for
changes within the company supply chain. In Figure 6 a segmented line highlights how links among EP can be derived from the problem connections in the NoP.

PS1 has been discarded since the risk of saturation for lines 1 and 2 was too high. Regarding the PS4, the company has immediately considered the opportunity to increase its employee number contracting a new operator: for Pb4 they decided to select the left path. The other employee has been relocated in the same plant, but into a new working position.

Finally, it is also interesting to underline that the separation in time principle has inspired also PS5, even if, in that case, no contradictions have been identified: the final results is the suggestion of a more efficient usage of time resources by performing the replacement during the maintenance period of the plant.

**STEP 5 - Solution evaluation: assessment of the changes to be implemented in the supply chain integration strategy.**

In this last stage, the identified evaluation parameters (Table 3 and Figure 6) can be used to assess the possible effects that the identified solutions could generate on the company supply chain strategy: in that case study quantitative values have been retrieved, as reported in Table 4.

**5. Conclusions**

Currently available supply chain integration models help decision makers to choose the best compromise solution among several alternatives, but they rarely guide the implementation stage in terms of what are the possible consequences or effects to take into account. The research described in this paper has a twofold objective: to define a more structured approach to solve integration problems avoiding compromise solutions and to support decision makers in accomplishing that integration. An important prerequisite in defining authors’ method has been to provide a decisional tool easy to use and understand, keeping the problem analysis traceable and taking into account supply chain distinctive features. An algorithm has been developed to guide organizations in correctly approaching and solving integration issues: OTSM-TRIZ resource analysis and Problem Flow Network (from the construction of the Network of Problems to the derivation of a Network of Contradictions) has been applied to come out with an efficient and reliable algorithm. The findings and lessons retrieved from the case study development and from the company experts’ involvement, such as production and human resources managers, are of two kinds: about the algorithm effectiveness and about the level of usability of the proposed approach. Regarding the algorithm effectiveness, the obtained results have been evaluated as effective, but additional case studies should be planned to test the algorithm robustness (i.e. considering new kinds of problems related to the supply chain integration strategy). Regarding the approach usability, further improvements can be made. Specifically, the authors consider this study as a first seed to build a software application capable to guide the analysis of a business process and the definition of a manufacturing supply chain following a systematic approach.

**References**


