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Research, Technological  
Development and Demonstration



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SCOOP

SHEET CUTTING AND PROCESS OPTIMIZATION for furniture enterprises

**SIXTH FRAMEWORK PROGRAMME  
HORIZONTAL RESEARCH ACTIVITIES INVOLVING SMEs  
CO-OPERATIVE RESEARCH**

***PUBLISHABLE FINAL ACTIVITY REPORT (24 months)***

Period covered: from Oct 16, 2006 to Oct. 15, 2008

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Revision 1

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## 1. PROJECT EXECUTION

### 1.1 Summary description of project objectives

This final activity report consists of brief information on key project action carried over the full duration of the project (16 October 2006 – 15 October 2008). The purpose is to report on the progress in terms of activities and results in coherence with the Project Programme. The document intents briefly to show and describe the objectives and results achieved according to the project work plan.

SCOOP is a Cooperative Research project supported by the European Commission in Sixth Framework Programme (Contract number: COOP-CT-2006-032998). The aim of this European Project is to develop an advanced software tool designed to manage the cutting process of wood based panels. This tool must minimise the panel's waste, considering the processing sequence of the pieces, because the efficiency of the production process depends on the organization of the pattern sequence. In fact, a part type is generally produced by several cutting patterns, and lots of parts of the same type are output by the system only when all the patterns producing that part type have been activated. In particular SCOOP is a Cooperative Research project aiming to improve the production for the small to medium sized furniture industries, as well as for the semi-finished goods companies that employ C.N.C. panel sizing centres (see fig. 1).

The most relevant problem in wood-working enterprises consists in an optimal selection of standard stock sizes and cutting stock sheets into smaller pieces according to specified requirements (number and type of pieces, cut and machine features, plan layout etc...) so that the waste is minimized. The efficiency of the production process also depends on the organization of a good production scheduling and a good cutting pattern sequence in order to minimize the maximum number of open stacks improving the automated material handling systems (see fig. 2).

In particular, the main goal of the project has been the development of technologically advanced software tools to being used to support the cutting operations in the furniture industry in order to:

1. Reducing the cost of the raw materials usage in the furniture industries by means of:
  - a. waste minimization through the adoption of optimal sets of cutting patterns,
  - b. optimal reuse of material, when applicable,
  - c. optimal stock size selection;
2. Improving the internal and external logistics by means of:
  - a. work-in-process minimization through optimal sequencing of cutting operations,
  - b. optimal stock size selection to reduce stock assortment,
3. Enabling and facilitating the introduction of automated material handling systems
  - a. minimization of the maximum number of open stacks through optimal pattern sequencing,
  - b. specification of a Manufacturing Execution System (MES) based on Advanced Process Control (APC);
4. Improving the internal organization of labour
  - a. standardization of cutting operations,
  - b. improvement of the cutting process, e.g., reduction of the number of machine set-ups and the set-up times,
  - c. improvement of material handling through optimal stock size selection,
  - d. reduction of part transfers in the shop floor through optimal pattern sequencing.

From the preliminary analysis conducted in the firsts months of the research comes out that the main organizational problems lie in the interaction between cutting operations and work in process management. However, the mutual impact of panel cutting and cutting pattern sequencing has rarely been a subject of study and only little commercial software considers this aspect.

During the first stages we have been compiling information about the panel cutting process in Italian and Spanish companies, because the software specification should be created taking into account real users' needs.

According to the compiled information we observed as many deficiencies in Spanish companies as in Italian companies. The companies consider that they must overcome these deficiencies to produce in ideal conditions. The biggest problems detected were unavailability of machines and tools (33% of companies in both countries), and lack of qualified operators (18% in Spain and 26% in Italy). Enterprises interviewed agreed that the main costs in the production process are labour and machines, rather than raw materials (between 36% and 43% of interviewed companies). Around 36-40% of companies, considered that material handling and transport are excessive.

The research project lasts *24 months*. Among the objectives mentioned above, the main ones have been reached during the first year and the first months of the second year through the development of advanced optimization algorithms. The development of a software prototype integrating the software artefacts started during the first year and it will be completed and tested during the second year.

The *main innovation* of the project consists in the conception of *automated cutting machines* equipped with control systems based on advanced *optimization methods*. The adoption of a system architecture, inherently flexible, that applies both exact and heuristic optimization methods recently developed mainly in the operations research field, it is considered by the partners of the project to be a *substantial step toward* the improvement in the management of panel sizing centres in furniture industries.

SCOOP Project focuses on Small and Medium Enterprises (SMEs) devoted to the manufacturing of semi-finished components and finished goods for furniture market by means of computer controlled wood-cutting machines and automated material-handling devices.

Several optimization problems arise and interact to each other in the context of industrial cutting processes. Among them, the most relevant surely is the *Cutting Stock Problem* (CSP) that consists in cutting raw material or semi-finite components according to a specified demand, technological constraints and organizational requirements while minimizing the total trim loss. The more general version of the CSP can be stated as follow: parts of given sizes must be obtained from stocks of given sizes so as to fulfil a pre-specified demand of parts associated to a planning horizon, and minimise the total trim loss.

However, the efficiency of the cutting process does not exclusively depend from the material usage. Also the organization of cuts, i.e., the cut sequence, can affect the total production costs. Indeed, each part type is generally produced by several patterns and lots of parts of the same type remain into the system until the last item of the relevant type is produced, i.e., until all the patterns producing that part type have been activated. The *Pattern Sequencing Problem* (PSP) deals with the scheduling of cutting patterns and with the optimization of some production parameters such as open stacks, intermediate inventory levels and weighted lot completion time. Mathematically speaking, the cutting pattern sequencing is a very difficult optimisation problem that still needs a significant effort of study. Finally, the cutting phase is just one step of a complex production process involving not only decisions about cutting operations of raw material, semi-finite and final components possibly performed in different (and distant) physical locations, but also production and inventory planning decisions (lot-sizing, transportation, storage, accounting etc.) having a non negligible impact on a significant part of the supply chain. From the preliminary analysis conducted

with furniture enterprises, partners comes out that the lot-sizing problem related to the incoming raw material (e.g., the stock size selection problem) is considered of marginal interest by the production managers. Therefore, the objectives 1.c (optimal stock size selection), and 2.b (optimal stock size selection to reduce stock assortment) have not been considered relevant during the development of the research activities: the RTD performers after the first technical meetings with the companies, they decided not to take them into consideration.

Instead, they believe that the main organizational problems lie in the interaction between cutting operations and work in process management. However, the mutual impact of panel cutting and cutting pattern sequencing has rarely been a subject of study and only few commercial software consider this aspect. The state of the art in this field shows that the automation of the cutting process is not efficiently optimised: the above problems are often considered as stand-alone and the available management and decision support systems are not tailored for SME's needs.

During the first year of the research project the following main objectives have been reached:

- a) the general organization and the production processes of SMEs operating in the furniture market have been analysed;
- b) optimisation models for plywood cutting stock and cutting pattern sequencing problems have been developed;
- c) optimisation algorithms and solution techniques for the above problems have been developed and tested;
- d) heuristic-search methods for the cutting sequencing problem have been developed and tested on real instances coming from furniture enterprises;
- e) the research results have been disseminated by the design of SCOOP website.

Whereas, the second year has been mainly focused to reach these objectives:

- f) Produce a prototype software of architecture based on the models and algorithms developed
- g) Testing the algorithms developed and make a comparison to existing literature
- h) Testing the methods developed on real problems and comparing them with commercial software used in partners enterprises
- i) To perform a structural design, a relational DB modelling and code development in C++, Java and .NET integrating all the SMEs available platforms.
- j) To include advanced optimization algorithms and heuristics in a user friendly interface usable by furniture employers.
- k) To provide an Integrated Software Prototype (ISP), sharable in intranet/extranet, easy updatable and customizable for SMEs
- l) Installation of prototype software in different furniture SMEs for testing.
- m) Testing of performances and optimization level achieved
- n) Comparative validation of quality and flexibility of prototype software
- o) Overcoming non-technological barriers related to the acceptance of IT tools
- p) Promoting awareness and sharing knowledge on the state of the art know-how and on what it is possible to do in order to improve furniture company performance and as to respond to market pressures for continuous innovation and processes optimization;
- q) To involve many other companies, also belonging to other sector, in order to frame new transfer hypotheses of research results.

All such objectives have been fully achieved within the following eight Work Packages:

WP 1: PROCESSES ANALYSIS AND TECHNICAL REQUIREMENT DEFINITION  
(LEADER CONTRACTOR: COSMOB)

WP 2: OPTIMIZATION MODELS FOR CUTTING, PACKING, SCHEDULING AND IN-PROCESS INVENTORY CONTROL (LEADER CONTRACTOR: UNIVAQ)

WP 3: OPTIMIZATION ALGORITHMS FOR CUTTING AND PACKING  
(LEADER CONTRACTOR: UMINHO)

WP 4: ALGORITHMS FOR PATTERN SEQUENCING AND PRODUCTION SCHEDULING  
(LEADER CONTRACTOR: UNIVPM)

WP 5: SOFTWARE PROTOTYPE DEVELOPMENT FOR SHEET CUTTING AND PROCESS OPTIMIZATION (LEADER CONTRACTOR: SOFTEL)

WP 6: TESTING OF SOFTWARE PROTOTYPE IN CONSORTIUM FURNITURE SMES

WP 7. PROJECT MANAGEMENT AND MONITORING

WP8: EVALUATION AND DISSEMINATION OF RESULTS (LEADER CONTRACTOR: COSMOB)

## **1.2 Contractors involved**

### **SMEs**

- Mobilpref SpA – Ancona (I) - Semi-finished furniture articles;
- Softel Srl. – Terni (I) – Software and ICT solutions development;
- Benicarlò Moble 2000 s.l. – Benicarlò (E) - Furnishing design and production.

### **RTD performers**

- Università Politecnica delle Marche (UNIVPM) - Dipartimento di Ingegneria Informatica, Gestionale e dell'Automazione -Ancona – (I) - Project Coordinator;
- Università degli Studi di L'Aquila (UNIVAQ)- Dipartimento di Informatica – L'Aquila (I);
- Universidade do Minho – Dept. Producao e Sistemas (UMINHO)- Braga (P).

### **OTHER ENTERPRISES and END-USERS**

- COSMOB Consorzio del Mobile – Pesaro (I) – Service center for furniture industry;
- AIDIMA - Valencia (E) – Asociación de Investigación y Desarrollo en la Industria del Mueble y Afines

### **Co-ordinator contact details**

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## 1.2 Work performed, major achievements and degree to which SCOOP objectives have been achieved

The main achievements for each WP have been the following:

- **WP1:** Analysis of the cutting processes and definition of the technical requirements in Italian and Spanish furniture enterprises, in order to provide data input for the following work packages. The main objective of WP 1 has been to deliver a report concerning the analysis of manufacturing processes and the definition of enterprise requirements. Such report has been used as input data by the successive work. The work package started working out a questionnaire having the aim of analyse the state of the art of the Italian and Spanish companies in the furniture industry. The questionnaire has been submitted to a selected list of Italian and Spanish enterprises respectively by COSMOB and AIDIMA. Once all the results have been gathered, a whole interview data analysis has been done. The main objective of this work-package has been to deliver a process and flows analysis report, and this has been delivered through deliverable 1 (D1).
- **WP2:** The activities of WP 2 have been mainly focused on the objective of developing a closed-loop heuristic algorithm for minimizing trim loss using a limited number  $s$  of open stacks. The starting point of work has been a column generation-based heuristic algorithm with a closed-loop architecture which seek for a set of cutting patterns that minimizes trim loss under the important technical constraint of being schedulable by requiring a limited number of open stacks over time. Three algorithm configurations were developed: One standard and two advanced. In all the configurations a Linear Programming (LP) solver has been used to obtain the linear relaxation solutions of staged cutting stock problems, as described in deliverable 2 (D2). In the second year advanced algorithm versions using dual-driven search and partial pricing has been developed to reduce the computational effort. Finally it has been a fourth algorithm version which includes both the advanced features described above and replaces the pricing oracle by one designed for 2-dimensional 2-staged guillotine cutting patterns, and the LP solver by a shareware one. The algorithm has been tested on real two-dimensional instances of the unconstrained version of the cutting stock problem provided by Mobilpref. The outcome is very interesting and promising: near-optimal solutions were found in all cases in fraction of seconds.
- **WP3:** The activities of WP3 have been mainly focused principally on the objective of the development of the algorithm testing and the comparison of computational results with those by existing literature. The main objective of this work-package has been to deliver a research report with identification of the innovative aspects of the problem and comparative computational study of algorithms developed with other algorithms proposed in literature through deliverable 3 (D3). The main achievement for the second year was the conclusion of the research with the development of algorithms to minimize the trim loss in cutting stock problems and comparative computational study on real problems of the partner enterprises of the algorithms developed delivered in the deliverable (D4). The optimization tools developed were integrated into a package that can be accessed by the Graphical User Interface developed by SOFTEL and integrated with other algorithms developed in the project. Extensive computational tests were performed to assess the quality of the algorithms, solving instances provided by partners (BM2000 and Mobilpref) and instances generated randomly. The computational tests for the instances provided by the partners have been effectuated for the heuristic and exact algorithms developed in WP3 and for the algorithms currently used by the companies, Optiplanning and Optisave respectively, have been compared using the same type of cutting procedure (choice of setting) in both

algorithms. The current versions of the heuristics developed produce results that are consistently better than the results presented in the literature and have been compared favorably, in terms of waste, with the software currently used by Mobilpref and BM2000.

- **WP4:** The main objective of this work-package in the first year has been to deliver a research report about algorithms for the solution of the cutting pattern sequencing problems and comparative computational study of algorithms developed. The main objective of pattern sequencing was to minimize the number of pallets required by a sequence, i.e. the maximum number of open stacks around wood-cutting machines (MOS). Furthermore among patterns sequences having the same MOS, it has been chosen the sequence, which has minimum time of open stack (TOS), i.e. the time in number of different cutting patterns that stacks remain open, so as to reduce the order dispersion of the pieces among the cutting patterns. This report includes depth survey of existing work in recent literature about solution techniques for pattern sequencing problems and for the integrated cutting-stock and pattern-sequencing problem. Moreover, a detailed survey has been developed on available commercial software for panels cutting. These achievements have been delivered through deliverable 5 (D5). The main achievement for the second year was the conclusion of the research on genetic algorithms to solve the minimization of the maximum number of open stacks. It consists in the deliverable (D6) realized and in the testing of the developed methods on real problems of the partner enterprises and the comparison of results with those by the existing literature. The optimization tools developed, based on metaheuristic methods for cutting pattern sequencing in automated panel sizing systems, were integrated into a package that can be accessed by the Graphical User Interface developed by SOFTEL and integrated with other algorithms developed in the project. The activities related have been fully accomplished developing metaheuristics methods based on genetic algorithms to minimize the Maximum number of Open Stacks (MOS) and Time of Open Sacks (TOS). Finally, a new version of the genetic algorithm has been tested on both real instances provided by Mobilpref and BM 2000 partners and benchmark instances from the literature obtaining optimal solutions with reduced computational times and compared favorably, in terms of the MOS, with the software currently used by Mobilpref and BM 2000. Furthermore, in the second year different alternative coupling schemes for pattern sequencing and cutting stock problems have been designed integrating metaheuristic methods for pattern sequencing developed by UNIVPM and heuristic methods for cutting stock developed by UMINHO (see an example in fig.3). Subsequently these methods have been implemented in the software prototype developed by SOFTEL (D7).
- **WP 5:** This WP - Software prototype development for sheet cutting and process optimization - is mainly dedicated to Software Prototype project and development both for general software architecture and GUI definition. The premises for software implementation had been the general system requirements and the functional specifications, that have determined what exactly the target application must do. All requirements have been thoroughly defined and documented.  
The optimization algorithms and techniques experimented in WP3 and WP4 had been integrated in the user prototype software. The main achievement of the work-package has been the production of an integrated software prototype coded in C++, Java and Microsoft .NET languages. The software, implement both an optimization for the generation of the cutting schemes (CSP) and an optimization for the Pattern Sequencing (PSP) based on high quality and high performances optimisation algorithms. All the processes optimized data and

strategies had been properly sent to the software environment and stored in a relational database for user presentation. A proper E/R model has been implemented and tested starting from the SMEs specifications already experienced with cutting optimization software. This integrated software prototype including graphic user interface and external database management represent Deliverable 7 (D7). The most important software features and characteristics have been presented in a draft user manual. This manual has also been translated in Italian because Italian SMEs wood panel working personnel are not particularly skilled with English language.

**WP 6:** This WP is concerned with the testing activities of the optimization software performed inside Consortium SMEs Mobilpref and BM2000. The main achievement was a report delivered in D8 containing the results and the considerations made during these tests. Deep organizational different situations between Mobilpref and BM2000 have been encountered. Mobilpref cuts the panels for his customers (cut optimization is very important, typically no over-production is made), instead BM2000 is a company that directly produces furniture (cut optimization is not so crucial, overproduction is normally done).

Real instances of Mobilpref and BM2000 using SCOOP optimization software have been tested. The aim to make to a general purpose application has determined a great involvement of RTD performers for corrective actions and new strategies for the optimization algorithms. The most important issue that significantly modify the optimal solution are items rotations, number of cutting stages and maximum number of different types of item allowed for each board. A further analysis of market software in terms of parameters setting for meeting custom needs has been made too directly contacting optimization software.

A comparative analysis of computational results with the market software already used from Consortium SMEs (Optisave for Mobilpref and Optiplanning for BM2000) has been made. Finally an evaluation of software performances both for cutting (CSP) and sequencing (PSP) has been carried out (see a real case in fig. 4 and 5).

The final activities of this work package have been the actions for overcoming non-technological barriers related to the acceptance of IT tools.

In particular some learning modules for SME woodworkers have been developed concerning SCOOP optimization software, cutting and sequencing optimization techniques, evaluation of optimization in terms of performance indexes.

The developed training modules for employers regarding labour organization and optimization software use are available on SOFTEL proprietary E-learning platform E-Lite (<http://www.e-lite.biz>). These activities are reported in Deliverable 9 (D9).

**WP 8:** Regarding the evaluation activity, it has been developed a questionnaire aimed to evaluate the project progress. This questionnaire has been used by the coordinator as tool to evaluate the project progress; this tool has been submitted to all partners.

For what concern the dissemination activity, was created a project web site as foreseen in the project work plan, so as to spread and enhance project results and create links with all other stakeholders' websites. The official SCOOP Project Web site is available at the url:<http://www.scoop-project.net/>. Web site, visited by about three thousand users, has been developed by SOFTEL with the contribution of the other partners concerning the technical and scientific contents (see D11)

Concerning the dissemination activity, the project web site was continuously updated so as to spread and enhance project results and news through COSMOB newsletters to all relevant stakeholders.

The main events organised, or to which the most of partners have participated, to disseminate SCOOP results and research activities have been:

- FIMMA (International Fair of Woodworking Machinery) and MADERALIA (International Suppliers Fair for Furniture and Wood Industry) 7- 10th November 2007, Valencia, [http://www.fieretv.com/feria\\_ficha/FIMMA+Madralia+2007/ief23/](http://www.fieretv.com/feria_ficha/FIMMA+Madralia+2007/ief23/) (AIDIMA);
- COSMU (FURNITURE and HABITAT SECTOR INTERNATIONAL CONGRESS) held in Valencia the 5 and 6th November 2007, <http://www.infurma.es/es/formacion/noticia/194.es.html> ,(AIDIMA);
- 13º Congresso da APDIO (Portuguese Association of Operations Research), IO2008, Universidade de Trás-os-Montes e Alto Douro (UTAD), Vila Real, Portugal, 17-19 March 2008.
- 5th Euro Special International Group on Cutting and Packing (ESICUP) International meeting at L'Aquila 21-22 April 2008 (UNIVAQ-UNIVPM), <http://www.fe.up.pt/esicup/extern/esicup-5thMeeting>
- "Column Generation 2008" International Workshop on Column Generation held in Aussois, France in June 17-20, 2008.
- XYLEXPO Biennial world exhibition for woodworking technology held in Milano the 24<sup>th</sup> June 2008, <http://www.xylexpo.com/eng/index.cfm?id=5>
- International Workshop: Wood furniture sector outlook innovation, growth and Development, Pesaro, 30th June 2008, <http://www.cosmob.it/> (COSMOB);
- Associazione Italiana di Ricerca Operativa (AIRO), Annual Conference, Ischia (Italy), September 2008, <http://www.airo2008.unina.it/> ;
- Scoop Final Conference on “Innovative systems for the optimization of production processes in SMEs of the furniture sector” “ Ancona, 2 October 2008, [www.scoop-project.net](http://www.scoop-project.net) (UNIVPM – COSMOB)
- Scientific workshop at University of Minho, Braga (Portugal) 13 October 2008.

Moreover articles and publications on scientific journals developed in the project by RTD partners are reported in details in deliverable 12 (D12).

Other articles and information have been printed and inserted in the sector Magazine (both paper & digital magazine) called AIDIMA INFORMA which was spread and distributed to all consortium companies in Spain. The dissemination work done woke the interest by some Spanish companies which have been in touch with AIDIMA staff. Therefore AIDIMA guaranteed they would be informed about the progress and how to prove the new software. Besides ADIMA, such kinds of activities have been also guaranteed in Italy by COSMOB, the partner leader of the WP 8 through: Brochure reprint (see fig.6), Web-site Updating (see fig.7), Dissemination Plan Updating and the participation to sector Italian fairs.

### 1.3 Methodologies and approaches employed

The research activities, which started at the beginning of the first year and lasted till the second month of the second year, have been developed in strict cooperation amongst the three Universities: the Università Politecnica delle Marche- Dipartimento di Ingegneria Informatica, Gestionale e dell'Automazione (IT), the Università dell'Aquila- Dipartimento di Informatica (IT) and the Universidade do Minho- Dept. Producao e Sistemas (P).

Research activities have been carried out through the implementation of the WP 2- *Optimization models for cutting, packing, scheduling and in-process inventory control*, WP 3 – *Optimization algorithms for cutting and packing*, WP 4 – *Optimization algorithms for pattern sequencing and production scheduling*.

The tree RTD partner have developed optimization models and advanced exact and heuristic optimization algorithms to solve both cutting stock problem and pattern sequencing problem

in an integrated approach. Such algorithms have been integrated in the software prototype developed by SOFTEL.

Evaluation of efficiency and effectiveness of the algorithms has been obtained by:

- collecting real problem instances and, when not sufficient for a sufficiently large test bed, using benchmark instances available in literature;
- classifying problem instances according to size and type; testing according standard measurement of algorithm efficiency and solution effectiveness;
- comparison of alternative solution methods with results obtained by commercial software utilized in Mobilpref and BM 2000.

To do that, RTD performers had several technical meetings each other to which it was fundamental the participation of the SOFTEL, the partner company in charge of the software design and development (WP5). Moreover, it was also really important the strong cooperation by the other two SMEs partners which provided the Universities and SOFTEL on necessary data to test SCOOP software on their own instances and interesting suggestions to improve the algorithms developed (WP6). Such approaches allowed the achievement of the relevant objectives within each work package.

#### **1.4 Achievements of the project related to the state of art: impact of the project research sector and on its industry**

The main result achieved have been:

- Advanced optimization methods to solve complex problems arising in the management and control of cutting processes adopted by European SMEs in the furniture sector
- Advanced software tools to support a wide set of operations related to the wood-cutting process in the European furniture industry
- A prototype of decision support software able to integrate the state-of-the art optimisation features for cutting stock, production scheduling, pattern sequencing in systems control modules of automated panel-sizing centres.

The optimization problems arising in the furniture industry are very complex, and in general SMEs are not able to efficiently solve them without external collaboration.

The main innovation of this project is the conception of automated woodcutting machines equipped with control systems based on advanced optimization methods. These methods represent the core of software tools used by CNC machines for wood panels cutting.

The resorting to new heuristic and exact optimization methods recently developed in literature is a substantial step toward the planning and control of flexible manufacturing systems for the furniture enterprises.

The meetings with SMEs allowed making aware company managers of the potential of the optimization methods to improve the cutting process. The experimentation on real data of the last version of the software created by SOFTEL allowed making comparisons between the results achieved by the developed algorithms and those obtained by the commercial software such as Optisave of the GIBEN International and Optiplanning of the BIESSE Group, which are currently used respectively by Mobilpref and BM2000.

Moreover SCOOP software put in evidence a clear improvement of the trim loss for the cutting stock problem and the maximum number of the open stacks simultaneously opened in the pattern-sequencing problem.

Finally we can say SCOOP optimization software benefited woodworking SMEs in several ways.

First, participating SMEs has improved their ability to enhance production results in term of performances indexes.

The SMEs also acquired valuable expertise. This will allow the companies to continue their technology adoption efforts, for example conducting a technology evaluation to determine their next software purchase.

By applying the methods learned through SCOOP, the company can identify a strategic capability, can examine candidate software packages, negotiate with the vendor to obtain the software they want, and implement their optimization strategies without help from SCOOP personnel.

Furthermore, the body of knowledge gained can help the SMEs to avoid many pitfalls, while streamlining their efforts, and improving their chances of technology adoption success.

The most important benefit for SOFTEL is to be the intellectual property rights (IPR) owner of SCOOP optimization software : The development of this software has been possible thanks to the strict collaboration with RTD performers and woodworking partner SMEs. The quality of results in comparison with other commercial software and the reported usability can be really interesting parameters for a future market placement of the optimizator. Contacts with sawing machines producers have been established during XYLExo exhibition in Milan and some of them are interested to test the software and to define a collaboration with SOFTEL in the next future.

Moreover, another important WP realisation delivered in (D9) was the planning of the training modules for employers regarding labour organization and optimization software use that are available on the e-learning platform of the SOFTEL Company (<http://www.e-lite.biz>).

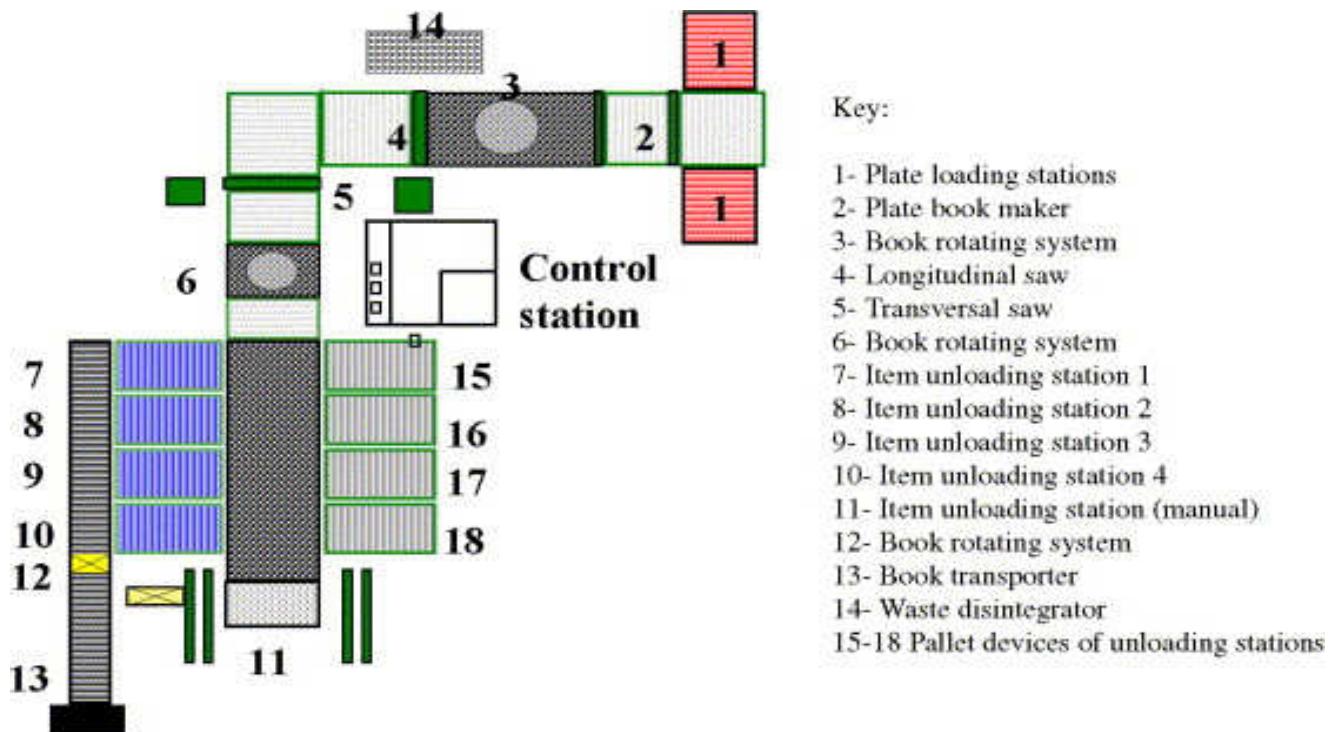
## **1.5 Short comments and information on co-ordination activities in the period**

Many work meetings have been made by coordinator together with COSMOB, SOFTEL and MOBILPREF in order to coordinate and focalise researches on necessities of SMEs partners. Visits to BM 2000 and Mobilpref plants have been useful to gather information and data on the cutting processes and software adopted by the enterprises. A number of real instances from Mobilpref and BM2000 have been collected and a database is now available. For each instance, the database contains the input and output data for the cutting stock and pattern sequencing problems. In particular, the output data actually are the results currently implemented by industrial partners in terms of both cutting patterns and related processing sequence. Also a database with a collection of literature benchmarks has been set-up. The minutes of transnational meetings are delivered in (D10).

## **1.6 Deliverables of the SCOOP project**

- D1- Processes and flows analysis report
- D2- Mathematical models and decomposition schemes
- D4- Final package integrating optimisation tools
- D6- Experimental results on real world problems
- D7- Integrated software prototype
- D8- Software testing results and comparative analysis with the previous performances
- D9- Training modules for employers regarding labour organization and optimisation software use
- D10-Preparation and circulation of minutes of meetings
- D11-SCOOP web site and Internet publications
- D12-Dissemination plan including publications and final conference

## 1.7 Photos and reference to the public website



**Fig. 1: Scheme of a panel-sizing center (cutting machine)**

From: Optimising the cutting of wood fibre plates in the hardboard industry, R. Morabito and L. Belluzzo, *EJOR*, 2007



**Fig. 2: An automated handling materials system for wood panels in an furniture enterprise**

Parts list			
Item code	Quantity required	Length	Width
1	16	977	1121
2	8	961	481
3	20	952	194

Summary					
Panel Length	Panel Width	Used panels	Total Waste (%)	MOS	TOS
2100	2550	14	22.42%	2	4

Pattern: 1 Repetitions: 4 Waste (%): 13,76%	Pattern: 2 Repetitions: 6 Waste (%): 31,02%	Pattern: 3 Repetitions: 4 Waste (%): 18,19%

Fig. 3: An example: parts list with cutting patterns and pattern sequencing optimization

Parts	Raw Materials	Cutting Layer	Sequencing					
	Company	Instance_File	Instance	Code_Item	Length	Width	Quantity	Description
►	Mobilpref	1460018	1	1	4230	5420	412	1460018
	Mobilpref	1460018	1	2	5730	5420	2060	1460018
	Mobilpref	1460018	1	3	8730	5420	412	1460018
	Mobilpref	1460018	1	4	4230	3200	412	1460018
	Mobilpref	1460018	1	5	5730	3200	824	1460018
	Mobilpref	1460018	1	6	8730	3200	412	1460018
	Mobilpref	1460018	1	7	8730	3730	206	1460018
	Mobilpref	1460018	1	8	5730	3730	206	1460018
	Mobilpref	1460018	1	9	4230	4450	103	1460018
	Mobilpref	1460018	1	10	4230	3730	412	1460018
	Mobilpref	1460018	1	11	4220	2900	412	1460018
*								

Fig. 4: Parts list included in a customer instance ordered by code item

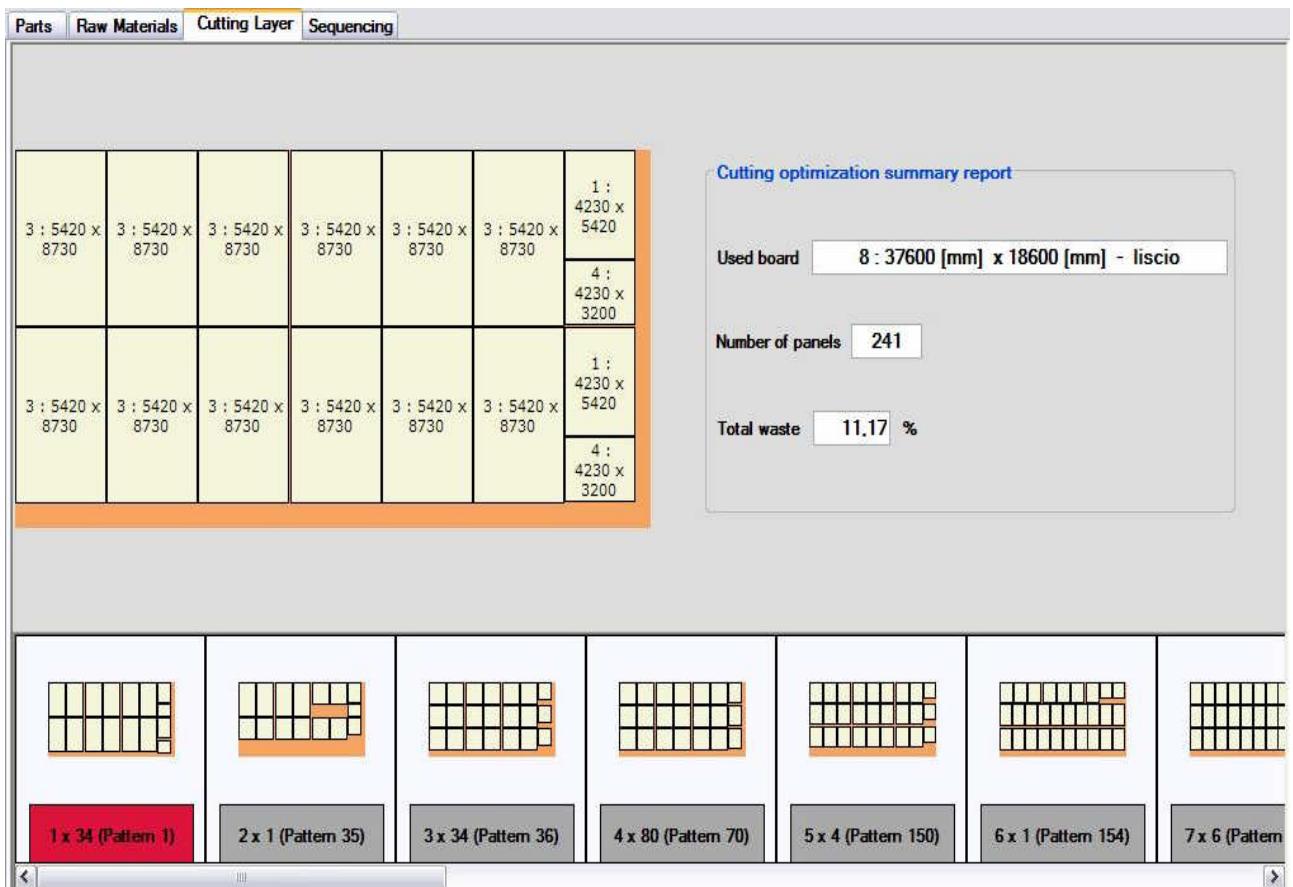


Fig. 5: SCOOP software: cutting patterns optimization with the number of used panels and total waste

**Background**

**SCOOP Project** is focused on **Small and Medium Enterprises (SMEs)** operating on semi-finished components by computer controlled wood-cutting machines and automated material-handling systems to produce finished good types.

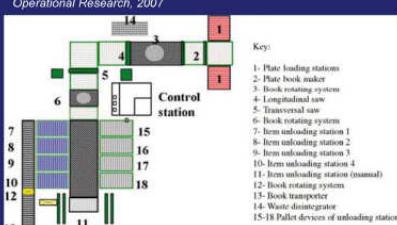
The most relevant problem consists in an optimal selection of standard stock sizes and cutting stock sheets into smaller pieces according to specified requirements (number and type of pieces, cut and machine features, plan layout etc.) so that the total trim loss is minimized (**cutting stock problem**).

The efficiency of the production process also depends on the organization of a good production scheduling and a good cutting pattern sequence in order to minimize set-up costs (**scheduling and pattern sequencing problem**).

A further type of problem is two- or three-dimensional pallet loading to improve the efficiency of material-handling systems (**packing problem**).

The state of the art in this field shows that the automation of the cutting process is not efficiently optimized: the above problems are often considered as stand-alone and the available management and decision support systems are not tailored for SME's needs.

**Scheme of a cutting machine**  
Source: Optimising the cutting of wood fibre plates in the hardboard industry, Fernando Morato and Luciano Belluzzo, *European Journal of Operational Research*, 2007



**SCOOP** SHEET CUTTING AND PROCESS OPTIMIZATION FOR FURNITURE ENTERPRISES

**PROJECT PARTNERS**

**RTD Performers**  
UNIVERSITA' POLITECNICA DELLE MARCHE, Italy  
UNIVERSIDADE DO MINHO, Portugal  
UNIVERSITA' DELL'AQUILA, Italy

**SMEs**  
SOFTEL, Italy  
MOBILPREF, Italy  
BENICARLO MOBLE 2000, Spain

**Other Partners**  
COSMOB, Italy  
AIDIMA, Spain

**PROJECT IDENTITY**

**Contract number:** COOP-CT-2006-032998-SCOOP  
**Duration:** October 2006 - October 2008 (24 months)

**Project Co-ordinator**  
UNIVERSITA' POLITECNICA DELLE MARCHE Ancona

**Contact Person**  
Prof. Ferdinando Pezzella  
Coordinator of SCOOP Project

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**SCOOP** SHEET CUTTING AND PROCESS OPTIMIZATION FOR FURNITURE ENTERPRISES

**THE DEVELOPMENT of INNOVATIVE SOFTWARE for the OPTIMIZATION of WOOD PANEL CUTTING**

**Objectives**  
SCOOP is a Cooperative Research project which aims to improve the production of semi-finished components in furniture enterprises using CNC machines for panels cutting. In particular the objectives are:

**Reduce the cost of the raw materials**

- optimal stock size selection in cases of two-stage cutting processes;
- minimization of trim loss through the adoption of optimal sets of cutting patterns;
- optimal reuse of material, when applicable.

**Improve the internal and external logistics**

- optimal stock size selection to reduce stock assortment;
- work-in-process minimization through optimal sequencing of cutting operations;
- optimal two- and three-dimensional pallet/container loading;
- minimizing the number of pallet/container used.

**Facilitate the application of automation systems**

- standardization of cutting operations;
- specification of a Manufacturing Execution System (MES) and manufacturing control systems based on Advanced Process Control.

**Improve the internal organization of labour**

- standardization of cutting operations;
- improvement of material handling through optimal stock size selection;
- reduction of part transfers in the shop floor through optimal pattern sequencing;
- reduction of machine set-up times

An automated handling materials system for wood panels in a furniture enterprise

**Expected Results**

The optimization problems arising in the furniture industry are very complex, and SMEs cannot generally solve them efficiently without external collaboration. The main innovation of this project is the conception of automated wood-cutting machines with control systems based on advanced optimization methods. These methods represent the core of software tools used by CNC machines for wood panels cutting. The flexible manufacturing system coupled with the new heuristic optimization methods recently developed in literature is a substantial step forward for planning and control of manufacturing systems for the furniture industry. The main expected results are:

- Optimization methods** to solve complex problems arising in the management and control of manufacturing processes and systems adopted by European SMEs.
- Advanced software tools** to support a wide set of operations related to the wood-cutting phase in the European furniture industry.
- A prototype of decision support software** able to integrate the state-of-the-art optimization features for cutting stock, production scheduling, pattern sequencing and pallet loading problems in automated manufacturing systems.
- The SCOOP project is expected to produce the following deliverables:

- Process and Flow Analysis report
- Report on mathematical programming and/or simulation, models decomposition schemes, flow charts and cost-to-benefit analysis
- Research report with identification of the innovative aspects of the problem and comparative computational study of algorithms developed
- Final package integrating optimization tools
- Report about algorithms for the solution of the problems formulated and comparative computational study of algorithms developed
- Experimental results on real world problems
- Integrated Software Prototype
- Software testing results and comparative analysis with the previous performances
- Software testing results and comparative analysis with the previous performances and training modules for employers regarding labour organization and optimization software use

Some of these WPs are carried out in parallel, in order to reduce the duration of this project.

**Supported by the European Commission**  
The SCOOP project is a "Cooperative Research" funded under Specific Research Projects for SMEs of the Sixth Research Framework Programme (Contract Nr. COOP-CT-2006-032998).

**Website**  
The Website disseminates information about the project, and is a virtual forum to allow exchange of experiences and opinions on common topics among the project's members. The SCOOP Website also facilitates the sharing of best practices among the furniture enterprises that use optimisation software for cutting processes of plywood.

A special newsletter is working to spread information on project's objectives and progress.

[www.scoop-project.net](http://www.scoop-project.net)

**fig. 6: Brochure of the SCOOP project**

For more information: [www.scoop-project.net](http://www.scoop-project.net)

SCOOP project - Sheet Cutting and Process Optimization - Mozilla Firefox

File Modifica Visualizza Cronologia Segnalibri Strumenti ?

Più visitati Come iniziare Ultime notizie

<http://www.scoop-project.net/index.php>

SCOOP THE SIXTH FRAMEWORK PROGRAMME SPECIFIC RESEARCH PROJECTS FOR SMEs - COOPERATIVE RESEARCH SHEET CUTTING AND PROCESS OPTIMIZATION FOR FURNITURE ENTERPRISES

**PROJECT**

- Project Summary
- Consortium
- Project Objectives
- Co-operative Research
- Potential Impact
- WP and Deliverables
- Workplan
- Dissemination
- Project Management

**EVENTS**

- Final Meeting
- Meeting Braga
- Meeting Valencia
- Meeting L'Aquila
- Seminario SCOOP
- Intern. WS Pesaro
- 5th ESICUP Meeting
- Kick Off Meeting

**UTILITIES**

- Cordis Official Site
- Gateway to the
- EURO Special Interest
- Constraint Modelling
- CRIMReGe

**PROJECT IDENTITY**

**Contract Number:** COOP-CT-2006-032998-SCOOP  
**Duration:** October 2006 - October 2008  
**Project Coordinator:** UNIVERSITA' POLITECNICA DELLE MARCHE - ANCONA

**Contact person:**  
**Prof. Ferdinando Pezzella**  
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**NEWS**

- + SCOOP News complete list
- Operations research Seminars a ...
- SCOOP RTD partners meeting in ...
- Operations research Seminars a ...
- SCOOP International meeting in ...
- SCOOP Italian partners meeting ...

**Furniture manufacturing**

**PRIVATE AREA**

- Documents repository
- Newsletter Administration
- WP Management
- Content management

**FURNITURE MANUFACTURING**

**SHEET-CUTTING PROCESS**

**SCOOP IMPROVEMENTS**

**OPTIMIZATION SOFTWARE**

**FINAL RESULTS**

**fanKounter**  
TODAY 4  
TOTAL 2624

**NEWS LETTER**

**Google SEARCH**

Completato

Fig. 7: SCOOP web site

## 2. DISSEMINATION AND USE

The main objectives of the SCOOP Project Dissemination Strategy can be listed, in brief, as following:

- ◆ To create awareness and to communicate project results and benefits to widest possible audience.
- ◆ To target specific audiences that will benefit from the results, in order to reach the largest number of European Furniture Companies and stakeholders.
- ◆ To identify and to use a variety of techniques as appropriate for the content to be delivered to target audience.

The main techniques used during the SCOOP Project were the following:

- ◆ ***Reports for internal circulation*** within the project, which objective are to:

- Fully document all data collected by the project and to ensure that all the partners have access to these data
- Provide sufficient analysis that the data can be understood and trends can be identified

There will be mainly three types of reports: minutes of meetings and actions agreed, presentations of workpackage progress update, SCOOP newsletters.

- ◆ ***Presentations at conferences and seminars, classes.*** These will be used in order to:

- Stimulate interest in SCOOP project results and potential benefits
- Reach wide and varied audiences
- Stimulate discussion and feedback

Presentations are short and should be focused and cover limited topic in an interesting and stimulating way. The emphasis should be on results, conclusions, models, issues and implications, not on data and methodologies.

All partners are encouraged to use opportunity to make presentations at conferences organized by their own organization. a standard PowerPoint presentation is available on the reserved area the SCOOP project portal ([www.scoop-project.net](http://www.scoop-project.net) ).

- ◆ ***Workshops and expositions***, as for conferences, are opportunity to share results and stimulate discussion. The format allows more detailed presentation of results. Partner' organizations will also use the opportunity of disseminating information at workshops organized by their own organization, as well as at workshops to which they are invited.

- ◆ ***Publications***, articles, posters and other literature that communicate the detailed activities, results and benefits of the project. Publications will be the main way that the project communicates results and conclusions to the outside world. The objectives for using publications are to:

- Communicate project results widely
- Reach specific audiences that will benefit from the results
- Enhance the professional profiles of project participants and prestige of their institutions

Publication may include peer reviewed journals (print or electronic), key magazines, trade magazines, conference proceedings, and book. Some partners have their own magazines, for those project partners will be encouraged to publicize the project through articles.

- ◆ ***Use of the SCOOP website, other partner' websites*** and electronic media in order to generate awareness of the project. The project website (<http://www.scoop-project.net/>) will be used to carry information about the project at both a summary and at a detailed level. For the partners will be available a specific access to a dedicated page and to the workprogrammes.

Moreover, the tools that have been used for the Dissemination activity are the following:

- ◆ ***Conference, seminars, exhibitions and classes:*** their advantages are the high profile and the high contact with audience. These tools require high level of resources, and they could have a potentially low impact on practice. So the profile depends on nature of the event and speakers.
- ◆ ***Conference proceedings:*** the target of this tool are only the readers of specialized press
- ◆ ***Newsletters:*** provide a clear and effective way to disseminate the results of the project. They can be distributed to a mailing list of partners' contacts, and are a good means of introducing new people and organizations to the project's work. But to write a newsletters requires significant resources and partners collaboration.
- ◆ ***Publicity leaflets:*** the aim of this tool is to disseminate the project at the public level. The persistence of the information during time is high and can be relatively low cost.
- ◆ ***Poster:*** this tool must be used with key audiences because the project is synthesized into a single image.
- ◆ ***Newspapers:*** an article can help to “get a name” and can be a good way to promote results of research, even if its impact is hard to evaluate.
- ◆ ***Trade magazines:*** are useful for disseminating relatively detailed information about the project outcomes.
- ◆ ***TV and Radio:*** media have potential to reach a large audience, to raise the profile and to make an impact. But some negatives points:
  - Insufficiently targeted
  - Can be hard to access
  - May need assistance of a press agency, which could be costly
  - The radio and local newspapers may be interested in the overall implications of the project for the local economy
- ◆ ***Website:*** The internet offers a good scope for disseminating the project outcomes, even if can only be effective with experienced users and if the right keywords are used within search engines
- ◆ ***Internet links:*** facilitate the research of the website and increase the dissemination.

In the following tables are reported the **publishable results** of the project:

<b>Result n° 1: Research report on mathematical programming models and decomposition schemes</b>
<b>Description of exploitable result</b>
Development and testing optimisation models for the cutting stock and pattern sequencing integrated problem taking into account SMEs peculiarities in the furniture enterprises. Design, development and testing of an integrated heuristic algorithm with a closed-loop architecture to find a set of cutting patterns that minimizes trim loss under the important technical constraint of being schedulable by maintaining over time a limited number of open stacks
<b>Possible market application</b>
Market of machinery and systems involved in processing wood, glass and stone Software services for production optimisation in furniture enterprises
<b>Stage of development</b>
Research
<b>Type of collaboration sought or offered</b>
Industrialization and commercialisation
<b>Type of partner sought and task to be performed</b>
Mechanics industry that designs and manufactures machinery and systems used to make furniture, doors and windows, as well as complementary items from wood, glass and stone. Software house that designed application software used to program the numerical control machines and to solve various woodworking problems, commercialisation of software
<b>IPR granted or published</b>
<ul style="list-style-type: none"> <li>- 5<sup>th</sup> ESICUP Meeting, L'Aquila, April 2008 <a href="http://www.fe.up.pt/esicup/extern/esicup-5thMeeting">http://www.fe.up.pt/esicup/extern/esicup-5thMeeting</a></li> <li>- Cologne Twente Workshop on Graphs and Combinatorial Optimization, Gargnano (Italy), May 2008</li> <li>- AIRO 2008 Conference, Ischia (Italy), September 2008, <a href="http://www.airo2008.unina.it/">http://www.airo2008.unina.it/</a></li> <li>- Graph and Optimization Meeting 2008, Saint-Maximin la Sainte Baume (France), August, 2008.</li> <li>- Scientific papers submitted for publication in international journals: <ul style="list-style-type: none"> <li>1. A. Aloisio, C. Arbib, F. Marinelli, Cutting Stock with no Three Parts per Pattern: Work-in-process and Pattern Minimization, submitted to <i>Discrete Optimization</i>.</li> <li>2. A. Aloisio, C. Arbib, F. Marinelli, On LP Relaxations of the 1-Dimensional Pattern Minimization Problem, submitted to <i>Networks</i>.</li> </ul> </li> </ul>
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<b>Result n° 2: Research report and comparative computational study of algorithms developed</b>
<b>Description of exploitable result</b>
Development and testing optimisation algorithms for the two-dimensional cutting stock problems taking into account furniture enterprises peculiarities. Design, development and testing branch and price exact algorithms and local search heuristic algorithms to minimize the trim loss.
<b>Possible market application</b>
Market of machinery and systems involved in processing wood, glass and stone Software services for cutting processes optimisation in furniture enterprises.
<b>Stage of development</b>
Research
<b>Type of collaboration sought or offered</b>
Industrialization and commercialisation
<b>Type of partner sought and task to be performed</b>
Mechanics industry that designs and manufactures machinery and systems used to make furniture, doors and windows, as well as complementary items from wood, glass and stone. Software house that designed application software used to program the numerical control machines and to solve various woodworking problems, commercialisation of software
<b>IPR granted or published</b>
<ul style="list-style-type: none"> <li>- APDIO Conference on Operation Research, Villareal (Portugal), 2007. <ul style="list-style-type: none"> <li>- 5<sup>th</sup> ESICUP Meeting, L'Aquila, April 2008, <a href="http://www.fe.up.pt/esicup/extern/esicup-5thMeeting">http://www.fe.up.pt/esicup/extern/esicup-5thMeeting</a></li> <li>- Column Generation, Aussois, France, June 2008</li> </ul> </li> <li>- AIRO 2008 Conference, Ischia (Italy), September 2008, <a href="http://www.airo2008.unina.it/">http://www.airo2008.unina.it/</a></li> </ul> <p>Scientific papers published in international journals:</p> <ul style="list-style-type: none"> <li>- Cláudio Alves, J.M. Valério de Carvalho, A branch-and-price-and-cut algorithm for the pattern minimization problem, RAIRO Operations Research, 42, pp. 435-453, 2008.</li> <li>- Cláudio Alves, J.M. Valério de Carvalho, New Integer Programming Formulations and an Exact Algorithm for the Ordered Cutting Stock Problem, Journal of the Operational Research Society, 59, pp. 1520–1531, 2008.</li> <li>- Cláudio Alves, J.M. Valério de Carvalho, A Stabilized Branch-and-Price-and-Cut Algorithm for the Multiple Length Cutting Stock Problem, Computers and Operations Research, 35, 4, pp. 1315-1328, 2008.</li> </ul> <p>Scientific paper to appear in international journal:</p> <ul style="list-style-type: none"> <li>- Rita Macedo, Elsa Silva, Claudio Alves, Filipe Alvelos, J, Valerio de Carvalho, Ferdinando Pezzella, Luigi De Giovanni, Luca Gambella, Claudio Arbib, Fabrizio Marinelli “2D cutting stock optimization software survey” OR/MS today publication of INFORMS – The Institute of Operations Research and the Management Science ( available on <a href="http://www.scoop-project.net">www.scoop-project.net</a> )</li> </ul>
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<b>Result n° 3: Research report and comparative computational study of algorithms developed</b>
<b>Description of exploitable result</b>
Development and testing optimisation algorithms for the cutting pattern sequencing problems taking into account furniture enterprises that use panel sizing centres. Design, development and testing methaeuristic based on genetic algorithms to minimize the maximum number of the open stacks.
<b>Possible market application</b>
Market of automated cutting machines involved in processing wood, glass and stone Software services for cutting processes optimization in wood working enterprises.
<b>Stage of development</b>
Research
<b>Type of collaboration sought or offered</b>
Industrialization and commercialisation
<b>Type of partner sought and task to be performed</b>
Mechanics industry that designs and manufactures machinery and systems used to make furniture as well as complementary items from wood, glass and stone. Software house that designed application software used to program the numerical control machines for panel sizing centres and to solve various wood working optimisation problems, commercialisation of software.
<b>IPR granted or published</b>
<ul style="list-style-type: none"> <li>- AIRO 2007 Conference, Genova (Italy), September, 2007</li> <li>- EURO XXII International Conference, Prague, July, 2007</li> <li>- 5<sup>th</sup> ESICUP Meeting, L'Aquila (Italy), April 2008, <a href="http://www.fe.up.pt/esicup/extern/esicup-5thMeeting">http://www.fe.up.pt/esicup/extern/esicup-5thMeeting</a></li> <li>- International Workshop “Wood furniture sector outlook innovation, growth and Development”, Pesaro (Italy), June 2008, <a href="http://www.cosmob.it/">http://www.cosmob.it/</a></li> <li>- AIRO 2008 Conference, Ischia (Italy), September 2008, <a href="http://www.airo2008.unina.it/">http://www.airo2008.unina.it/</a></li> </ul> <p>Scientific paper to appear in international journal: Rita Macedo, Elsa Silva, Claudio Alves, Filipe Alvelos, J, Valerio de Carvalho, Ferdinando Pezzella, Luigi De Giovanni, Luca Gambella, Claudio Arbib, Fabrizio Marinelli “2D cutting stock optimization software survey” OR/MS today publication of INFORMS – The Institute of Operations Research and the Management Science ( available on <a href="http://www.scoop-project.net">www.scoop-project.net</a> )</p>
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<b>Result n° 4: Optimization software prototype for cutting(CSP) and sequencing(PSP)</b>
<b>Description of exploitable result</b> Integrated software prototype, implementing CSP and PSP optimization, with a user-friendly GUI and an external relational database management system.
<b>Possible market application</b> Optimization of Sawing and Cutting in CNC machines for woodworking Software services for cutting processes optimization in woodworking SMEs.
<b>Stage of development</b> Prototype
<b>Type of collaboration sought or offered</b> Industrialization and commercialisation
<b>Type of partner sought and task to be performed</b> Mechanics industry that designs and manufactures machinery and systems used to make furniture as well as complementary items from wood. Software house that design specific application software for numerical control machines used in panel sizing centres
<b>IPR granted or published</b> - Not yet registered
<b>Contact details</b> Ing. Luigi Trollini Softel Srl Via Borsi 14, 05100 Terni (Italy) tel.: +39 0744406160 fax : +39 0744406160 <a href="mailto:luigi.trollini@sof-tel.it">luigi.trollini@sof-tel.it</a>  Prof. Ferdinando Pezzella Università Politecnica delle Marche Dipartimento di Ingegneria Informatica, Gestionale e dell'Automazione Via Brecce Bianche 12, 60131 Ancona (Italy) tel.: +39 2204826 fax : +39 2204474 <a href="mailto:pezzella@diiga.univpm.it">pezzella@diiga.univpm.it</a>

<b>Result n° 5: Software testing results and comparative analysis with commercial software</b>
<b>Description of exploitable result</b>
Report containing a comparative analysis of computational results regarding real instances from consortium SMEs Mobilpref and Benicarlò. The analysis has been made comparing the performance indexes obtained with commercial software (Optisave and Optiplanning) and with SCOOP optimization software.
<b>Possible market application</b>
Optimization of Cutting and Sequencing in woodworking European SMEs
<b>Stage of development</b>
Released
<b>Type of collaboration sought or offered</b>
No particular collaboration is needed. Comparative analysis should be useful for woodworking SMEs operating in the same situations of Mobilpref and Benicarlò for improving the efficiency of their production activities.
<b>Type of partner sought and task to be performed</b>
Mechanics industry that designs and manufactures machinery and systems used to make furniture as well as complementary items from wood. Software house that design specific application software for numerical control machines used in panel sizing centres
<b>IPR granted or published</b>
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