DA11.6: Implementation of the PLM Process model for the Demonstrator on Adaptive Production

Written by:
Maurizio Tomasella, POLIMI,
Andrea Matta, POLIMI

DELIVERABLE NO	DA11.6: Implementation of the PLM Process model for the Demonstrator on Adaptive Production
DISSEMINATION LEVEL	**CONFIDENTIAL**
DATE	15.04.2008
WORK PACKAGE NO	WP A11: PROMISE BOL information management for Adaptive production
VERSION NO.	V1.0
ELECTRONIC FILE CODE	DA11.6 v.1.0_bis.doc
CONTRACT NO	507100 PROMISE A Project of the 6th Framework Programme Information Society Technologies (IST)
ABSTRACT	This deliverable (DA11.6) summarises the implementation of the PLM process model for the A11 demonstrator, in terms of scenes, use of PROMISE components and technology, as proposed in previous DA11.x documents. The detailed results are given of the activities performed for the implementation including any deviations from the original plan.

STATUS OF DELIVERABLE		
ACTION	**BY**	**DATE** (dd.mm.yyyy)
SUBMITTED (author(s))	Maurizio Tomasella, Andrea Matta	05.06.2008
VU (WP Leader)	Maurizio Tomasella, Andrea Matta	05.06.2008
APPROVED (QIM)	Dimitris Kiritsis	06.06.2008

Revision History

Date (dd.mm.yyyy)	Version	Author	Comments
15.04.2008	V0.1	Maurizio Tomasella	Initial Draft
25.05.2008	V0.2	Maurizio Tomasella	A11 PDKM and DSS screenshots added and commented
03.06.2008	V1.0	Maurizio Tomasella, Andrea Matta	Version to be submitted to project internal peer review

Author(s)' contact information

Name	Organisation	E-mail	Tel	Fax
Maurizio Tomasella	POLIMI	maurizio.tomasella@mecc.polimi.it	+39 2 2399 8592	+39 2 2399 8585
Andrea Matta	POLIMI	andrea.matta@mecc.polimi.it	+39 2 2399 8591	+39 2 2399 8585

Table of Contents

List of figures

1 Introduction

1.1 Purpose of this deliverable

This deliverable describes the implementation of the PROMISE A11 demonstrator (PROMISE BOL information management for Adaptive Production) according to the design described in the preceding DA11.x deliverables (DA11.1, DA11.2, DA11.3 and DA11.4).

This deliverable fulfils milestones *MA3.3, MA3.4 and MA3.5: Implementation of the Process Model for Adaptive production (M30, M34 and M40)* and is the summary result of task *TA3.6: Implementation of the PLM Process Model for the demonstrator on Adaptive Production in the Teksid Aluminum case.*

1.2 Overview of the A11 demonstrator: objective and components

The objective of the A11 demonstrator is **to improve a PROMISE product's BOL businesses**, and more specifically **production-related** businesses.

The demonstrator consists in a software tool supporting a scenario previously described in details (DA11.1 through DA11.4 documents) and called **Adaptive Production**, as to indicate a new way of managing the processes of:

- adapting existing production resources/plants to modifications in the product design driven by field-data
- designing production resources/plants which are at the outset conceived so that that field-data driven future modifications in the product design are expedited

This software tool in turn consists of an implementation of the PROMISE PDKM, equipped with its PROMISE DSS component, and in particular with one of the PROMISE DSS software modules, namely the Adaptive Production module, providing decision support in the BOL phase.

The end-users of the Adaptive Production software tool are both Original Equipment Manufacturers (e.g. FIAT, GM, automakers in general, etc.) and their subcontractors (e.g. Teksid Aluminum), not only confined to the automotive sector.

The software tool can be used in any stage of the production process, independently from being used also in one or more of the remaining production stages. It is used by OEMs for internally-managed production processes, and by its subcontractors for production processes which OEMs have previously externalized to them.

In the former case, the tool enables a really complete closure of lifecycle information loops, also including the production phase in a real closed-loop PLM approach. The tool in fact enables the analysis and optimization of the implications field-data-driven product design improvements have on production-related businesses, which would not be possible without such a software tool.

In the latter case, the emphasis is on the way the process of analyzing a request of product modification (or of introduction of a new product variant), coming from the OEM, is supported, so that:

- an optimal design/modification of the production resources/plants can be obtained, in a way that the implementation of the product design modification can be economically attained
- this optimal design/modification of the production resources/plants can lead, in a short time, to the formulation of a commercial offer that is accepted by the OEM, and which thus brings new business "in the house" of the subcontractor.

In fact, generally, OEMs send the same request for quotation of a product modification or of a new product production to many potential competing sub-contractors at the same time (also those not presently producing the product under consideration); the subcontractor needs to respond to the OEM as soon as possible with a commercial offer, which must obviously ask for the lowest price among all the offers received by the OEM. To do this, the subcontractor must be supported by a tool enabling the shortest lead time possible to finalize the commercial offer, and providing the most accurate estimation of production costs, so that the commercial staff at the subcontractor has a contractual marginal power first in making the first offer and then in the eventually following chaffering/negotiation with the OEM.

Care was taken to avoid reproducing, in the requirements for the A11 demonstrator, decision making functionalities already provided by existing PLM suites, and in particular by existing Asset Management modules of these PLM suites, which represent the real competitor of the Adaptive Production software tool in the PLM solutions market. For a detailed comparison of the A11 demonstrator with the existing competitors basket please refer to document DA11.7.

One further objective of the A11 PDKM/DSS implementation was to demonstrate the overall corporate impact of the (partial) automation of the human decision making processes described in detail in the A11 Process Model (DA11.4 document). This is currently necessary to speed-up the process of adaptation of the design of the production resources/plants, in a collaborative fashion, i.e. by involving the right people at the right point in the process, and by providing new, fast and accurate analytical tools for optimal decision support.

1.3 Acknowledgements

Although this document is credited to a small number of authors, it is only fair to emphasise that the results being documented here would not have been possible without the enthusiasm and high level of both competence and commitment from the excellent team of people who have been also heavily involved in the design, development, integration and realisation of the A11 demonstrator:

POLIMI	Daniela Borgh, Davide Ferrari, Paolo Moriggi
Teksid Aluminum	Stefano Verdiani, Ernesto Barbero, Marco Pacca
CRF	Mario Gambera, Julien Mascolo, Gian Maria Secco Suardo

2 Specification of the A11 demonstrator (final version)

The specification of PDKM- and DSS-related functionalities of the A11 demonstrator have undergone a process of cyclic revision and improvement, while carrying out the different steps of the spiral development approach of the same software tool.
The different versions of this specification process, based on the always deeper collaboration with Teksid Aluminum on the one side, and on the willingness to make the tool exploitable for future implementations different from the Teksid Aluminum one, have been documented in previous A11 documents, though in a rather *disjointed* fashion. This means that different portions and different versions of the specification have been included in separate documents of different WPs.
The first important piece of specification was documented in DA11.4, by means of workflow models and information flow models. A second piece was documented by means of UML 2.0 use case diagrams and the related use case textual descriptions (this took place in several DA11.x, DR8.x and DR9.x documents). Hereafter, a final version of this specifications is reported.

2.1 A11 workflow models (business logic) and information flow models

2.1.1 "High-level" workflow models and information flow models

The "High-Level" workflows (business logic) represent the **workflows** regarding the A11 demonstrator **at a business level**: this section shows where, in the overall set of workflows involving the cooperation between FIAT and Teksid Aluminum, the A11 demonstrator operates.

In the A11 demonstration case, all begins (Figure 1) with a need for product modification, derived by FIAT from the field data collected on a specific product (e.g. the 4-cylinders engine head). FIAT then defines the specifications for the needed product modifications and delivers a detailed OPM (Order of Product Modification) to its suppliers (which is Teksid Aluminium, for the considered product). The OPM is generally represented by:

- the CAD models (.dwg files, .dxf files, etc.) of the modified product;
- a detailed document on the specific requirements related to the requested modification.

Typically, and coherently with the present environment in which modern companies work, only very few days are left to Teksid Aluminum to answer with a complete offer (two weeks at maximum).

At Teksid Aluminum then, a consistent portion of the human resources is allocated to the task of preparing a technical and commercial offer for FIAT. These resources are mainly constituted by the Teksid Aluminum internal users of the A11 demonstrator, which is developed specifically for this purpose.

Starting from the OPM received by FIAT, and with the aid of the A11 demonstrator, the commercial staff at Teksid Aluminum first creates an RPM (Request of Product Modification), i.e. an information object describing, internally to Teksid Aluminum, all of the pieces of information concerning the OPM received. All of the users are then able to start working on a consistent information base and to carry out the whole process of preparation of the offer for FIAT. The commercial staff is responsible for the creation of this information object. More details on this process will be added in the next pages.
After the RPM has been created, the technical staff, i.e. production system designers and manufacturing process designers, in particular those working at the Machining Department at Teksid Aluminum (the so called "Machining Platform Personnel"), first examine the RPM in all

its details, and then introduce into the A11 demonstrator, step by step, all the pieces of information needed to start the decision support functionalities of the same demonstrator. This leads to the understanding of which is the most profitable technical solution to the problem of reconfiguring the production (machining) process and systems, in order to accomplish the product modification requested by FIAT.

At the end of this complex decision process, whose workflows and information flows are also described in details in the next pages, the following pieces of information must be known:

- A description on the modified process, at the desired level of detail, to be used for the implementation of the required modifications, in the case FIAT accepts the offer;
- A description of the modified production system, at the desired level of detail, to be used for the implementation of the required modifications, in the case FIAT accepts the offer;
- An estimation of the production system physical performance with the modified configuration and the modified process cycle, at the desired level of detail, which provides an estimation of the throughput of the production system (pieces/hour);
- An estimation of the investment and operating costs related to the modified production system configuration performing the modified process cycle, at the desired level of detail, but at least sufficient to be used to estimate as accurately as possible the production cost for the modified product.

All these pieces of information are then used by the production system designers and the manufacturing system designers to prepare the TO (Technical Offer), which is for internal use inside Teksid Aluminum. The TO document has the following purposes:

- At first, it is used as a design document, in case the offer is really accepted, for the implementation of all the needed modifications;
- At second, it describes in a structured way, all the costs related to the adaptation of the production system and/or process to the OPM received.

After the work on the TO is completed, the commercial staff analyzes the details on the technical solution (starting from the investment costs) and, again with the aid of the A11 demonstrator, prepares the FO (Final Offer) document. Commercial details are added, after the commercial staff and the financial staff (also involved in the process, but only for this purpose) prepared a proper business plan related to the initial OPM document.

Once received Teksid Aluminum's offer, FIAT analyzes it, makes its decision and sends a feedback on the RPM to Teksid Aluminum, which is called here RPM status. Then three situations are possible:

- The offer is accepted, so Teksid Aluminum has to implement all the needed modifications on the production system (also called "production system adaptation") and on the process cycle and its operations;
- The offer is not accepted but a negotiation is initiated between FIAT and Teksid Aluminum;
- The offer is not accepted at all, because FIAT finds more convenient to accept the offer arrived in the meanwhile from another supplier (FIAT generally asks different potential sub-contractors to accomplish a given request of product modification, though the priority is given to the current supplier).

In order to avoid the third case, and possibly also the second case, which in turn means that the whole process of preparation of the offer must be rerun again another time, the following statements must hold:

- The lead time needed to prepare the whole offer and deliver it to FIAT must be very low, significantly lower than that of the competitors.
- The price proposed to FIAT should be as low as possible, in FIAT's perspective.
- The price proposed to FIAT must be as high as possible, in Teksid Aluminum's perspective.
- The unit production cost associated with the modified production system configuration must also be as low as possible.

By now, it should be reminded that some of the key aspects of the A11 demonstrator are as follows:

- For Teksid Aluminum internal users (commercial staff and above all Machining Platform Personnel), the A11 demonstrator represents a shared resource, with which they can take part together, each one playing her/his role of competence, to a high-valued concurrent engineering decision process.
  For an assessment of the overall business potential related to this decision making activity, please refer to deliverables DA11.2 and DA11.7.
- Compared to the current state, where almost no tool exists for the support of such business activities, some important advantages provided by the A11 demonstrator are the following:
  - the same approach and tools are used by everybody;
  - a common and consistent base for the insertion, modification, and management of RPMs can be also shared and used by everybody.

  This prevents both useless duplication of information on the one side, and a larger and useless number of passages of the same information (and in different formats) among the actors participating in the business process, thus lowering down the overall lead time for the preparation of the offer.

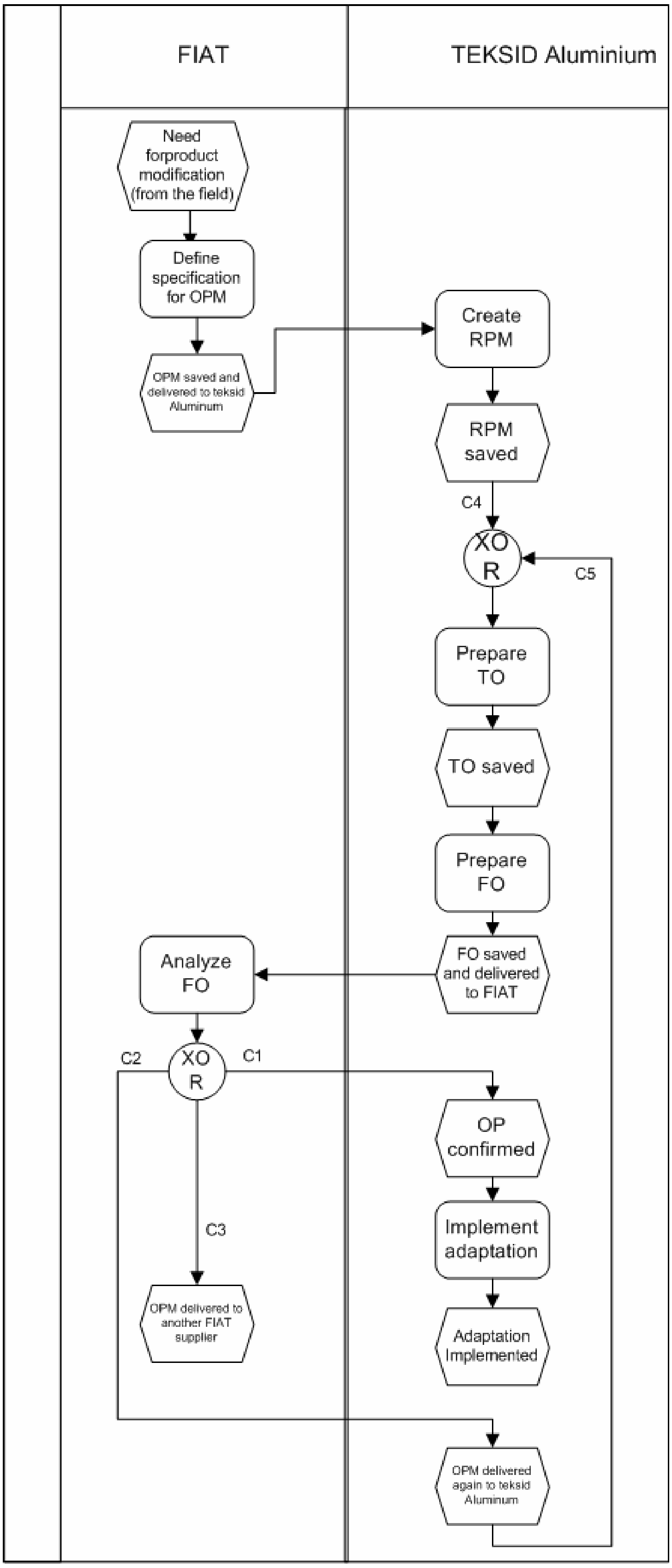

Figure 1: "High-Level" workflows for the A11 demonstrator

Figure 2 shows the basic information flows among the processes just described. It should be remembered that all begins with the field data on the product of interest (FD), and that all ends (in the best case) with the process/system modifications (IM), implemented at the shop floor level.

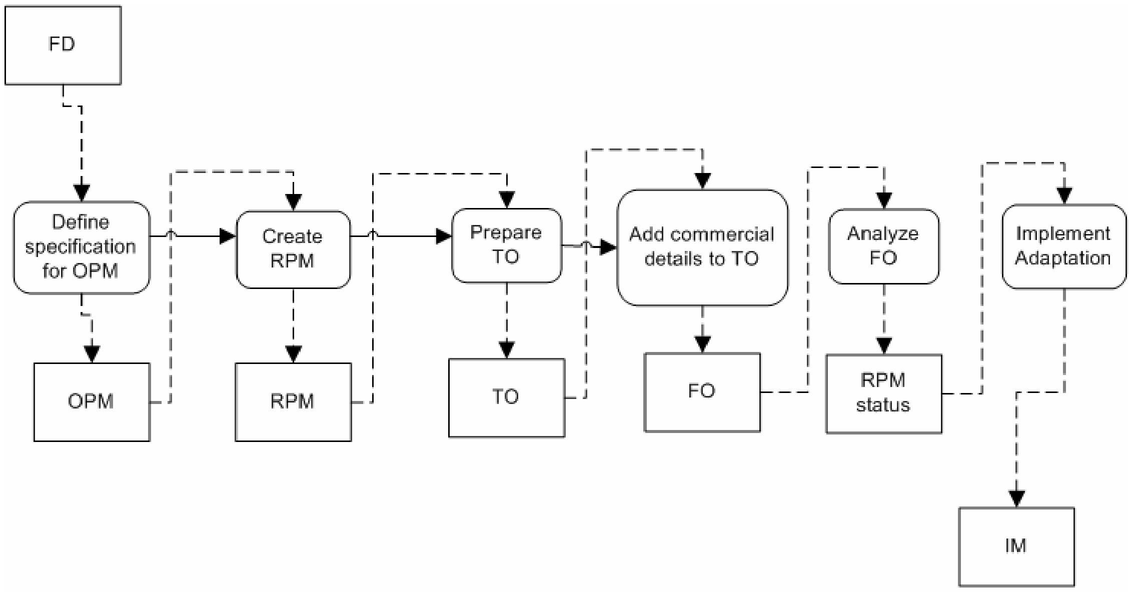

Figure 2: ”High-Level” Information Flows for the A11 demonstration case

2.1.2 Low-level workflow models and information flow models

This section shows the workflows and information flows related to the creation of the RPM and especially to the preparation of the TO document. These two workflows and information flows are placed at the “A11 demonstrator level”.

2.1.2.1 Creation of the RPM document

After the OPM has been received (Figure 3), the commercial staff at Teksid Aluminum starts the demonstrator tool, with the scope of creating the RPM related to the received OPM.

Note: in the EPC-like diagrams of the “Low-level” workflows, each column represents one of the software components of the A11 software demonstrator, as they were defined in previous DA11.x documents. For the definition of these software components, please refer to these documents. In the following treatment, the focus will be on the overall business process and on the specification of how the different steps of this business process are supported by the functionalities of the A11 demonstrator.

The first step is to insert the most general pieces of information via a user-friendly GUI. These pieces of information include:

- The identifier of the customer (e.g. FIAT).
- The identifier of the product type to be modified (e.g. the 4-cylinders engine head).
- The general description of the type of product modification (i.e. the specification of the nature of the modification, such as “modification of the feature XY-21”).

The second step for the commercial staff at Teksid Aluminum is to insert a set of specific pieces of information for the RPM. In particular:

- The detailed list of product features to be modified, together with the technical specifications of these modified features (dimensions and tolerances, above all).

- An estimation of the future demand of the product, over a pre-defined time horizon.

At this point, if the collected information is sufficient to provide Teksid Aluminum also with estimates for the future evolution scenarios related to the product configuration, the information already described in DA11.2 document for the definition of a proper "scenario tree" are also inserted. This information can be briefly reminded in the following:

- The number of different evolution stages considered.
- For each stage, the potential scenarios which could happen.
- For each scenario, a description of the product configuration, at the desired level of detail (mainly depending on what in the product is considered to be potentially subject to changes) and an estimation of the product demand.
- For each couple of scenarios linked together, specific information on the transition between one scenario and another, i.e.:
    - (eventually) the transition probability;
    - the lead time needed for the transition to take place.

It should be remembered that, from the very beginning of life of the product, many product features are known to be somehow "fixed", while some others are considered to be potentially subject to changes. The "fixed" ones cannot change mainly because of motivations such as:

- The feature is an interface to a feature of another component of the engine (or of the product, more in general), which cannot be modified due to technical constraints.
- The feature cannot be changed due to basic requirements the product must respect (e.g. the diameters of some functional round holes in the case of the engine).

The "modifiable" features are also known in advance, because of motivations such as:

- The feature is a "critical" feature for the considered product, in the sense that its "field performance" can mine the functionality of the product. Based on the field data collected, future modifications of this feature can be considered and then, based on the existing link between the product feature and the way the production system produces it, a proper adaptation strategy for the production system is derived and used to support the decisions of the manufacturing process and system designers (i.e. of the Machining Platform Personnel).
  This correspondence between the geometrical/technological definition of the feature and the configuration of the production system/process is a key aspect in the overall production system reconfiguration process.

- The feature can be differentiated over time due to different variants of the product which have to be produced in different time periods, but the sequence of variants in each period is not known in advance with certainty.

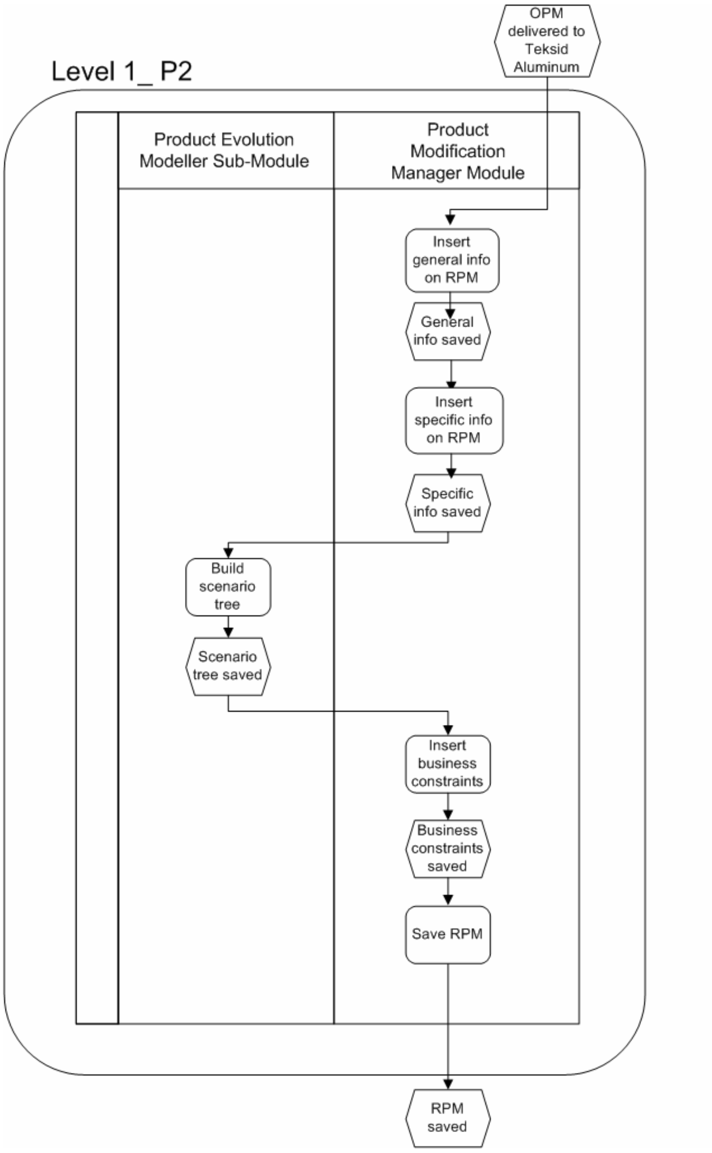

Figure 3: Workflows for the creation of the RPM in the A11 demonstration case

This leads to the final stage of the RPM creation process, where the business constraints, which must be then taken into consideration by the technical staff in the creation of the TO document, must be provided. This is done again by the commercial staff. The following business constraints are of particular interest:

- Budget constraints;
- Maximum unit production cost admitted for the modified product;
- Lead times admitted;
- Minimum throughput level to be satisfied.

Figure 4 provides a summary of the information flows considered in the creation of the RPM.

In conclusion, the described workflows and information flows present the detailed activities performed by the commercial staff at Teksid Aluminum, in order to set the main inputs for the following preparation of the TO document, where on the opposite only the Machining Platform personnel plays a part, by interacting with the decision support component of the A11 demonstrator. The workflows and information flows related to the preparation of the TO document are presented in the next section.

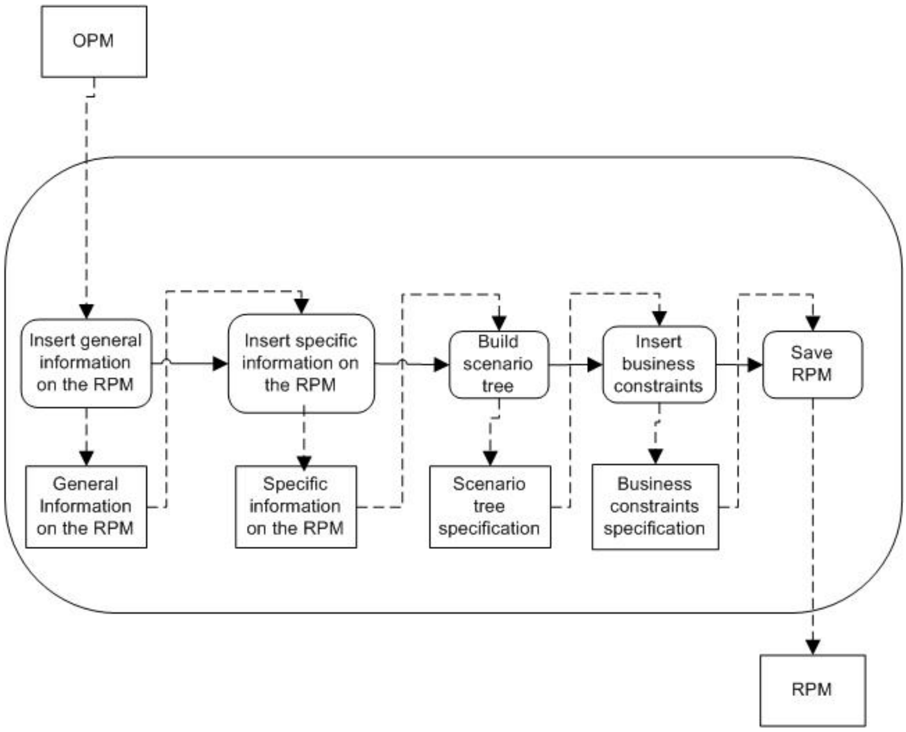

Figure 4: Information flows for the creation of the RPM in the A11 demonstration case

2.1.2.2 Preparation of the TO document

The first step in this process (Figure 5) is the detailed analysis of the RPM as it was saved by the commercial staff: the main browsing functionalities of the PDKM component of the demonstrator are used for this purpose. These browsing functionalities are used in general:

- by the commercial staff, when first creating an RPM and also when modifying an existing RPM, though this was not highlighted in the previous section;
- by the Machining Platform Personnel, in the analysis of an RPM discussed here.

After the analysis has been carried out by both the designers, the manufacturing process designer starts the Process Modification Manager Module and, by browsing the structure of the information on the process cycle on the one hand, and by using her/his expertise and knowledge on the other hand, inserts a (small) set of variants for the considered manufacturing cycle.
No optimization tool is designed and implemented in the demonstrator for this purpose, mainly because the available resources are not sufficient to develop such a tool in a way for it to be competitive with the efficiency of the human expertise. Nevertheless, this optimization component could be added in future developments of the Adaptive Production software tool.

The provided set of variants for the manufacturing process are then analyzed and used by the production system designers. These must first of all choose between one of the two available modes of use of the decision support component of the A11 demonstrator, both of which are described below.

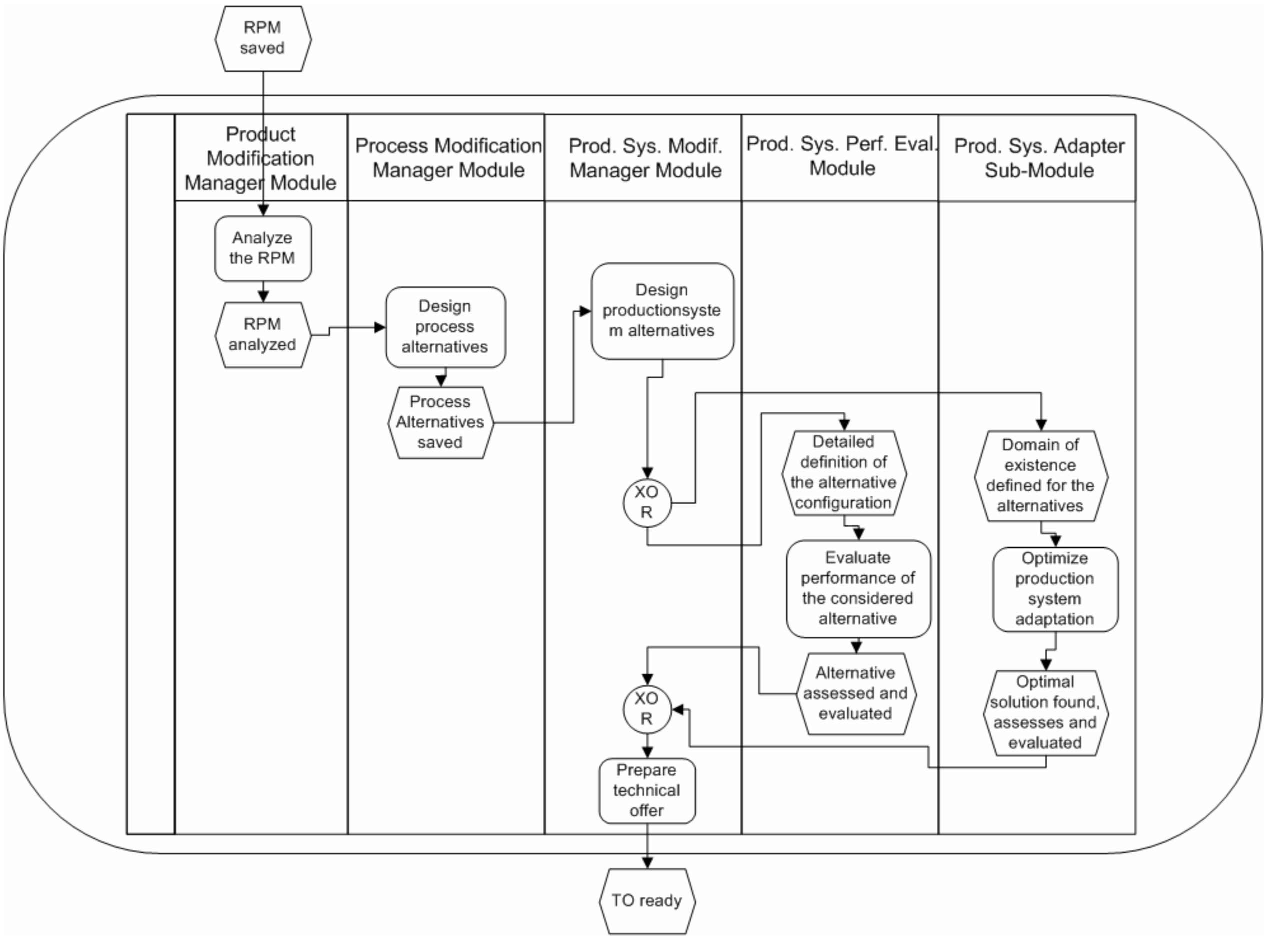

Figure 5: Workflows for the preparation of the TO in the A11 demonstration case

What … If? Analysis

In case the production system designer wants to carry out a *What…If? Analysis* approach, she/he starts the DSS component of the A11 demonstrator, specifying the chosen mode of use. A specific GUI is then utilized to define a set of production system configurations in all the needed details. This also represents itself an important innovation for production system designers at Teksid Aluminum, since no aid is currently available to carry out this process.
In this mode of use, the human expertise and knowledge represents the basis for a successful reconfiguration, and the production system designers are asked to enter directly the specifications for the system configurations which must be then assessed and evaluated.

These assessment and evaluation processes are carried out by the production system designers, for each of the considered production system configurations: this evaluation must provide (at least) an estimation of the physical performance of the production system, i.e. of the throughput (parts produced per hour). This is the minimum required to calculate a rough estimation for the unit production cost of the modified product, as well as the first step for the commercial staff to decide which price should be proposed to FIAT for the received OPM. It is not the case to highlight here the importance played by the proposed price in the possibilities of an automotive supplier to meet the customer's requirements and subscribe a contract for the supply of the considered product.

The evaluation process is, in the A11 demonstrator, completely automated and based on analytical methods and simulation: by means of this, a precise estimation can be derived in a relatively short time. Though being only the minimum required, this would represent a breakthrough contribution for the PROMISE DSS technologies, in particular in the Teksid Aluminum case, where this evaluation process is basically manual and above all requires, in the best case, a lot of time, i.e. days (the analytical methods require, in the best cases, only few seconds).

This is not however the only output information provided by DSS component for this mode of use; the complete set of pieces of information also includes, for each investigated production system configuration:

- The estimation of the production system performance (throughput);
- The estimation of all operating costs, based on the estimated performance;
- An estimation of the NPC (Net Present Cost) calculated for a time period specified by the user, considering both the investment costs for adapting the production system configuration over time, and the operating costs related to the modified configuration.

All this allows the production system designer to define the so-called TO, also specifying all of the costs related to the adaptation of the manufacturing process and of the production system in order to meet the requirements provided by the OPM.
The control of the whole business process returns then to the commercial staff, which can thus prepare the most profitable offer for FIAT. For the workflow to be continued, the remaining business processes of the “High-Level” workflow diagram are executed at this point (no EPC diagram is provided for them, since in the Teksid Aluminum case the focus is on the two process of the whole chain, i.e. “Create RPM” and “Prepare TO”.

Production System Reconfiguration

If the production system designer wants the to run the DSS component of the A11 demonstrator in the Production System Reconfiguration mode of use, the first difference is that the same component shows another set of screenshots of the GUI, with which the user can specify the domain of definition for the production system configuration.

This is used to find out the optimal solution in terms of production system reconfiguration, minimizing a cost function which is developed as a synthesis of the manufacturing strategy applied at Teksid Aluminum.

The main difference to be stated at this point, between the workflows of the two modes of use, is that in this second case the optimization process requires a larger number of evaluation of the production system physical and economical performance set, one for each configuration generated during the optimization process.

In Figure 6, the information flows related to the considered workflows are also reported for completeness.

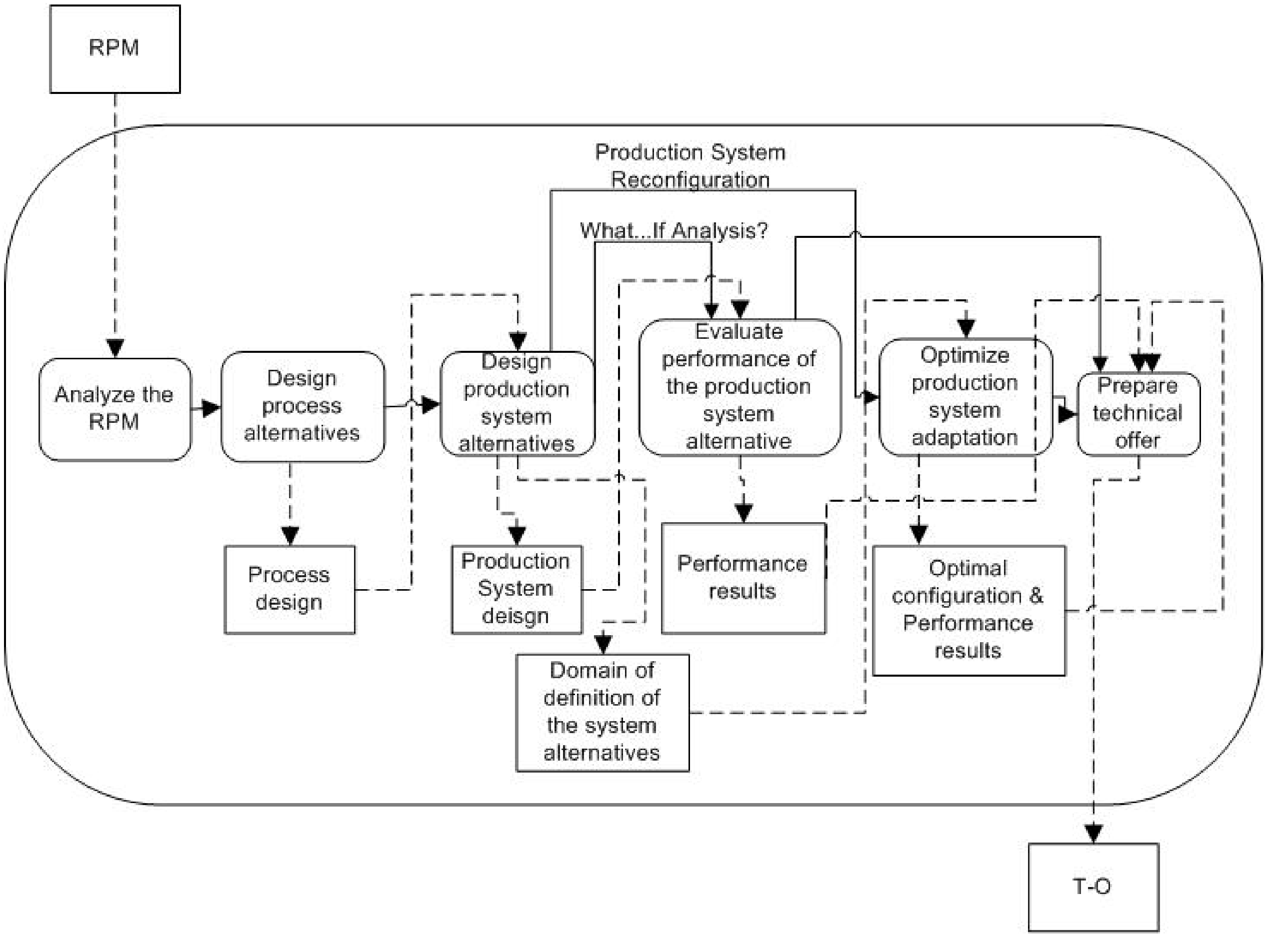

Figure 6: Information flows for the preparation of the TO in the A11 demonstration case.

2.2 PDKM-related specification

PDKM Specification for the A11 Application Scenario and Demonstrator

Here, the specification of the PDKM-related functionalities needed by the A11 demonstrator, are presented, by means of an UML use case diagram and of the related textual specifications for each use case.

The PROMISE A11 Application Scenario basically concerns, in the PROMISE PDKM viewpoint, the management of information on product types and of a number of related documents. No information on product instances. No field data. Product Structures (of product types) are also addressed by the scenario. In addition, information on production systems, with details on their layout and specific components (machines, material handling devices, etc.) and on production processes (machining cycles) are also involved.

These pieces of information are stored:

- In the PDKM DB, with respect to product types and structures, production systems and related structure and components, machining cycles, in form of PDKM data objects, according to the technical data model representing the PROMISE PDKM Object Model
- In appropriate documents, with respect to the rest of the pieces of information, which are represented by files of different formats (.pdf, .doc, .dwg, .dxf, etc.), attached to the PDKM data objects, and also contained in the PDKM DB

Document types to be managed by the PDKM component of the A11 demonstrator, are symbolically listed in the following (for more details on them, please refer to the previous section)

- **RPM**: Request of Product Modification
- **TO**: Technical Offer
- **FO**: Final Offer
- **OPM**: Order of Product Modification
- **IM**: Implemented Modification
- **D**: Drawing
- **PS**: Process Specification
- **SS**: System Specification

The creation of these documents happens (in a real-world system) in most cases “outside” of the PDKM system (basically in the DSS component of the overall PDKM instantiation), except for the **RPM**, **TO** and **FO** documents, where the creation of these documents happens “logically” inside the PDKM (and for this reason a specification is provided). Nevertheless, strictly speaking in terms of A11 demonstration purposes, which is more focused on the algorithmic part of the demonstrator and on the numerical information provided to the decision maker, the implementation of these “creation functionalities” for the **RPM**, **TO** and **FO** documents is not needed. Moreover, it would have to be too much case-dependent, on the GUI side, on the specific needs of Teksid Aluminum, and would not highlight the core concepts which are proven by the A11 demonstrator, which are indeed very general and thus provide the same demo with the potential to be further developed as a full-scale software product, in the future.

With reference to the PROMISE PDKM System functionalities, as they were previously described in document DR9.3, the table below shows which of the functionalities of the overall PROMISE PDKM system are required in A11 Application Scenario and Demonstrator.

PDKM function (DR9.3)	Required for both A11 Application Scenario and Demonstrator
Web Portal	X
Product and Product Structure Management	X
Configuration Management	
Field Data Functions	
Field Data Input	
Incidents Management	
Document management	X
Knowledge Management	
Data Analysis and Knowledge generation functions	X
Access Control	X
Additional SAP ECC 5.0 functions	(X)*

*=Only for specifying some particular kind of attribute for a product type. However, this is not a central issue.

In particular, A11 Application Scenario requires, <u>in terms of document management</u>, the following functionalities:

- Insert (Create) a new document (of a given type), related to a given product type. This should be possible, depending on the document type:

- By compiling a form (**RPM**, **TO** and **FO** documents), and then by saving what has been inserted into a new file of a pre-specified extension, depending on the document type.
- By selecting the interested file (**OPM**, **IM**, **D**, **PS** and **SS** documents) from an appropriate directory/location in the file system.

- Modify an existing document (only for the **RPM**, **TO** and **FO** documents), related to a given product type, and save the modifications either in the same file or in a new file of the same type. The rest of the document types can only be modified by appropriate DSS functionalities or other software systems.
- Delete an existing document (of any given type), related to a given product type.
- Browse existing documents for a given product type.

Focusing now, among those document management functionalities listed here above, only those required by the A11 demonstrator, i.e. those strictly needed for demonstration purposes, the previous list reduces to the following:

- Browse existing documents for a given product type.

Considering now PDKM requirements of the A11 Application Scenario and Demonstrator, different from the document management function, i.e. the rest of functionalities in the previous table, the requirements list follows:

- Browse existing product types and the related product structures
- Browse existing production systems and the related structures and components

Use Case Diagram of the A11 Demonstrator

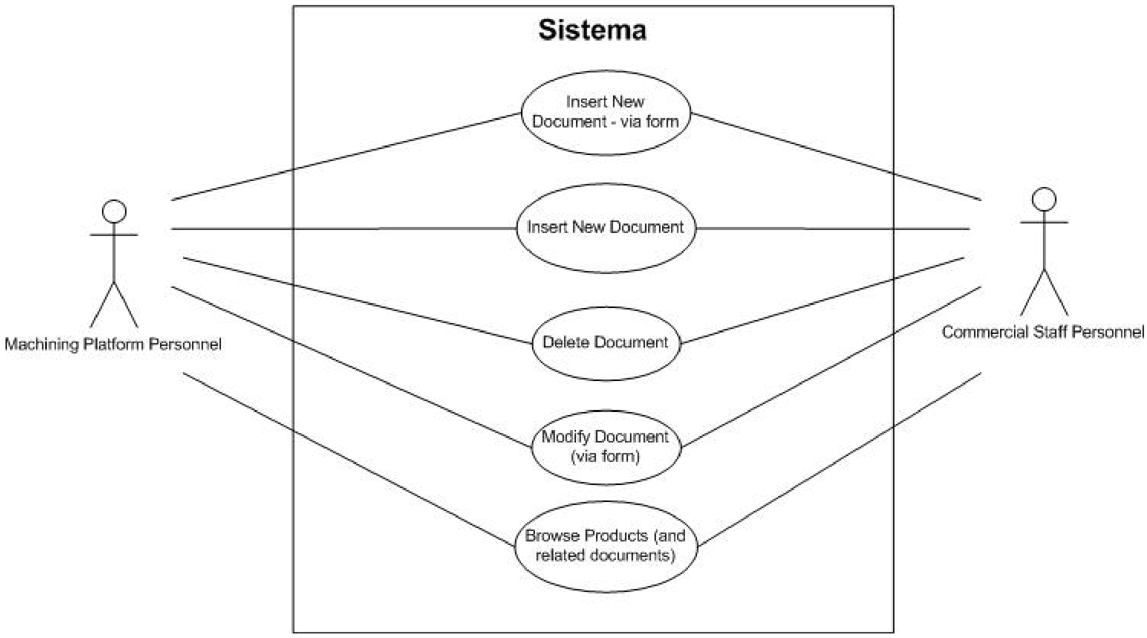

Figure 7: PDKM-related use case diagram

Specification of the represented use cases

In the following, detailed textual specifications are reported for each of the PDKM-related use cases reported above. These represent the final version of the PDKM requirements used for implementing the PDKM component of the A11 demonstrator, and are intended to replace all previous – and most of the times incomplete – versions of the same specification, shown in former

A11 working documents. The same textual descriptions are also available in the DR9.12 deliverable.

Insert New Document - via form

Actors	Machining Platform Personnel, Commercial Staff.
Pre-conditions	-The actor has logged into the system. -The document to be modified is of one of the following document types: RPM, TO, FO.
Triggers	The actor wants to insert a new RPM/TO/FO document.
Warranty	-
Main Success Scenario	1. The actor selects the functionality to insert a new document via form 2. The actor is presented with the related form, which is empty is the actor starts from scratch, otherwise is pre-compiled with some information, if the actor starts from an existing document of the same type. 3. If the actor owns the needed access rights, he can finalize the insertion of the new document.
Alternative Scenarios	If the actor does not own the needed access rights, he is prompted not to attempt to insert the new file and the deletion is aborted.

Insert New Document

Actors	Machining Platform Personnel, Commercial Staff.
Pre-conditions	-The actor has logged into the system. -The document to be modified is of one of the following document types: OPM, IM, D, PS, SS.
Triggers	The actor wants to insert a new OPM/IM/D/PS/SS document.
Warranty	-
Main Success Scenario	1. The actor selects the functionality to insert a new document from file. 2. The file is selected from the file systems. 3. The file is saved into the system and linked to the related product type.
Alternative Scenarios	-

Modify Document (via form)

Actors	Machining Platform Personnel, Commercial

	Staff.
Pre-conditions	-The actor has logged into the system. -The document to be modified is of one of the following document types: RPM, TO, FO.
Triggers	The actor wants to modify at least part of an RPM/TO/FO document
Warranty	-
Main Success Scenario	1. The actor selects a specific document he wishes to modify 2. The actor is presented with the related form, pre-compiled with the current status of information in the document. 3. If the actor owns the needed access rights, he can modify the document and save the modifications
Alternative Scenarios	If the actor does not own the needed access rights, he is prompted not to attempt to modify the file and the deletion is aborted.

Delete Document

Actors	Machining Platform Personnel, Commercial Staff.
Pre-conditions	-The actor has logged into the system.
Triggers	The actor wants to delete a certain document
Warranty	-
Main Success Scenario	1. The actor selects a specific document he wishes to delete 2. If the actor owns the needed access rights, he can delete the document
Alternative Scenarios	If the actor does not own the needed access rights, he is prompted not to attempt to delete the file and the deletion is aborted.

Browse Products (and related documents)

Actors	Machining Platform Personnel, Commercial Staff.
Pre-conditions	The actor has logged into the system.
Triggers	The actor wants to gather some kind of information on a specific product type and/or on its related documents
Warranty	The actor is able to browse all available information on the selected product type.
Main Success Scenario	1. The actor either selects, from the web-GUI, a specific product type, or inserts, via the web-GUI, the name of a known product type

	2. The actor browses the available documents on the product type (Drawings, RPMs, etc. – see list in page 1) 3. The actor browses the product structure, in case of complex products, and can select to move to the information at the components level.
Alternative Scenarios	-

2.3 DSS-related specification

Figure 8 shows the final version of the UML Use Case diagram for the DSS component of the A11 demonstrator.

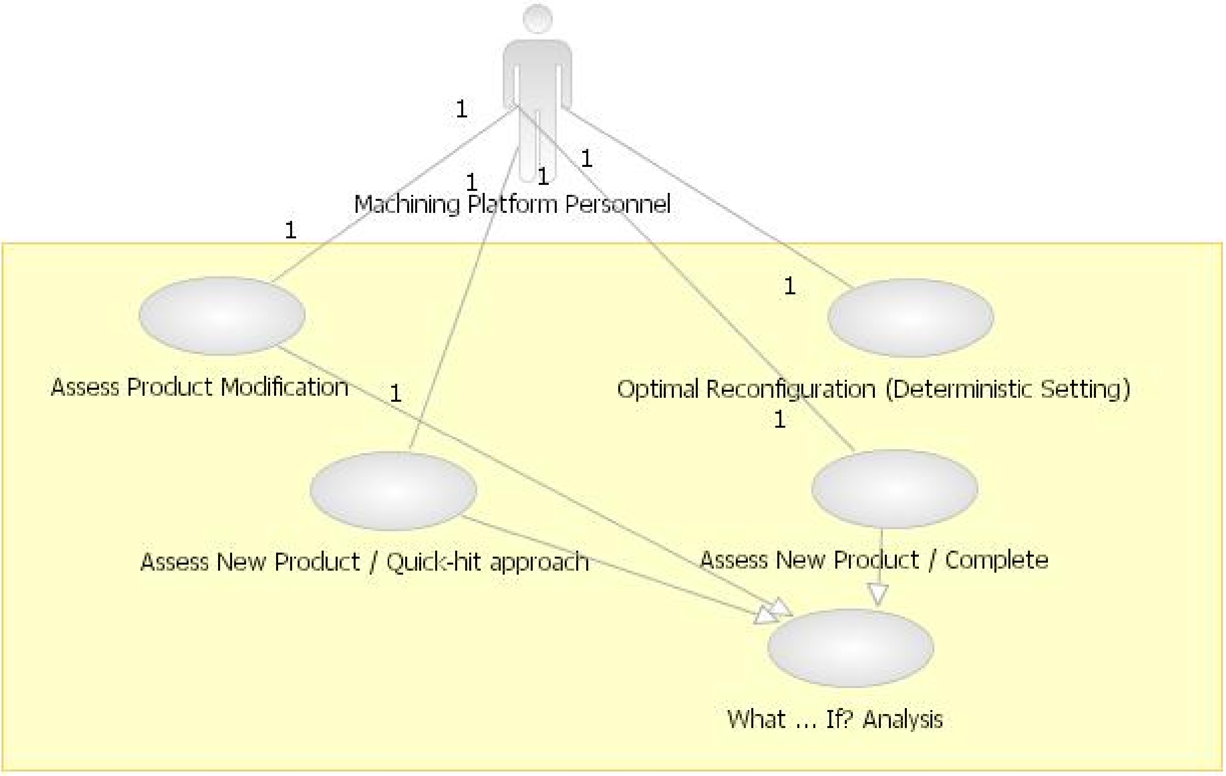

Figure 8: DSS-related use case diagram

There are two main classes of decision-support functionalities inside the A11 DSS demonstrator:

- The **What … If? Analysis** set of functionalities enables the user to carry out different kinds of analyses on the effect of a field-data driven change in the production process and/or production system, given as input a specific request of changing some of the technological features of a particular product and/or the demand level for the product of interest. The same analysis can be carried also out on a new product, and especially by evaluating many desired system and process configuration alternatives at the same time. The user must also be enabled to choose the set of outputs he desires and to change, where possible, the parameters of the computation (thus exploiting the full potential of the decision support tool, not only accepting a pre-packaged set of outputs calculated in a pre-defined way).

- The **Optimal Reconfiguration** functionality is recalled by the user when she/he wants to determine the optimal (n an economical sense) reconfiguration policy for the production system/process, given a certain production problem, where the product can vary over time not only in demand but also in its technological features. Please recall that these potential changes can be derived, in a closed-loop PLM approach, from the field data collected on previous products of the same type/family.

The users of the A11 DSS Demonstrator are **Error! Reference source not found.**(see the indicated actor) the production process and production system designers of the Machining Platform, which is the Technological Platform at Teksid Aluminum that most needs the A11 demonstrator.
The identifier of the actor in the Use Case Diagram, i.e. "Machining Platform Personnel", indicates the generic employee of the Machining Platform, who generally acts both as production process designer and as production system designer and who generally performs the whole decision making process. In case the two people are actually different (imaging another firm adopting the A11 demonstrator), each of them can use the portion of the tool and of the related interface that corresponds to his competence.

The What…If? Analysis set of functionalities is then subdivided into the following functionalities:

- Assess Product Modification
- Assess New Product / Complete
- Assess New Product / Quick-Hit Approach

In the following, a brief introduction for all of them will be provided.

Assess Product Modification. This is the most important "What..If? Analysis", in the PROMISE viewpoint.

Given the following:

- a product currently in production;
- a set of modifications the customer (e.g. FIAT) wants to be implemented into the same product;
- the currently available configuration of the shop floor in terms of current process cycle and current production system layout;

the user must be able to:

- change something he wants to assess and evaluate in the process and/or in the system (directly starting from the existing ones);
- save the defined alternatives;
- ask the system to make all the related evaluations in terms of economical and physical performance, with the precise objective of determining the most profitable alternative among those investigated.

Assess New Product / Complete. The user must be able to make the same decision as that of the Assess Product Modification functionality, but in relation to a new product, for which no current process cycle and/or production system is available (in general). The user must anyway be enabled to choose a process cycle and/or a production system among those saved previously into the system (obviously concerning products which are similar to the one under study, at least for the process), in order not to start from scratch but rather from existing solutions (these solutions are already stored and available in the DB of the PDKM component of the A11 demonstrator).

Assess New Product / Quick-Hit Approach. Sometimes the user does not have sufficient time to design a process cycle and or a production system in details, simply because the customer (again, FIAT) gave him only some hours in order to prepare an offer for a new product. In other situations the problem is not the available time itself but rather the information provided by the customer as input, which is not sufficient to design a realistic and detailed process/system (e.g. many customers deliver to Teksid® Aluminum only a jpeg picture of the raw piece to cast and machine, with only the surfaces to be machined highlighted and sometimes without any indication of the dimensions of the raw piece). In all these situations there must exist a tool which is capable at least to provide an estimate, as accurate as possible, of the unit production cost to machine the product under study. This tool must ask the user for only a small set of input data and must provide the results almost immediately; the typical input data in the Teksid® Aluminum case is:

- A global indicator of the required machining tolerances;
- A global indicator of the required surface roughness;
- A global indicator of the number and type of machining operations to be performed;
- The level of demand;
- The country of production.

Documentation of the defined use cases

All of the use cases shown in **Error! Reference source not found.** were further detailed by a correspondent textual description. For reasons of space, only one use case will be reported here. The aim is to show how each use case was developed in order to become the basis for its subsequent implementation.

Assess Product Modification

Actors	Machining Platform Personnel
Pre-conditions	The actor has logged into the system
Triggers	The actor chooses the "What … If ? Analysis" set of functionalities
Warranty	The actor has at least the possibility to view the details of a product currently in production, the requested modifications (i.e. the details of the RPM document related to the considered product), the current situation implemented in the shop floor (this last in terms of the detailed pieces of information on the process cycle and on the production system).
Main success scenario	1. The actor selects an RPM document from the list of existing RPM documents. 2. The system displays: - the identifier of the product type for which the related modifications are evaluated - the identifier of the currently implemented process cycle - the identifier of the currently implemented production system 3. The actor browses the details of the currently implemented process cycle and production system, and saves a certain number of alternatives of production systems and/or of production processes, which must be then evaluated. 4. The actor chooses which results he wants to be displayed on his screen. 5. The actor chooses which model parameters must be used in the evaluation process. 6. The actor confirms to the system that he wants the alternatives previously defined to be evaluated. 7. The system performs the requested evaluation.

	8. The system displays the results into the GUI. 9. The actor analyzes/browses the results of the evaluation process 10. The actor saves the results of the evaluation process, quits the system and the scenario ends.
Alternative scenarios	3a. The actor wanted only to browse the details of the selected RPM document. He then quits the system and the scenario ends. 4a. The actor agrees with the pre-defined set of outputs and does not make any change in their list. Go back to point 5 in the Main Success Scenario and continue with it. 4b. The actor quits the system and the scenario ends. 5a. The actor agrees with the pre-defined set of values for the model parameters and does not make any change in their list. Go back to point 6 in the Main Success Scenario and continue with it. 5b. The actor quits the system and the scenario ends. 6a. The actor quits the system and the scenario ends.

Note: given the functionalities described above, the RPM has been renamed, for implementation purposes, as RFQ (Request For Quotation); in this way both requests for assessing a product and a product modification are called with the same name.

3 Implementation of the A11 demonstrator

3.1 A11 PDKM DB specification and population

When implementing the PDKM component of the A11 demonstrator, and in particular the PDKM DB of the A11 demonstrator, a mapping between the A11 data requirements and the technical data schema of the same DB had to be carried out. This was performed by means of a mapping between A11 data and the proper "Transactions" in the SAP ECC 5.0 implementation of the DB. The results of this mapping activity is briefly sketched in the next table.

ECC 5.0 Transaction	Used in A11
Material	X
Equipment	X
Class	X
Characteristic	X
Measuring Point	
Measurement Documents	
Document	X
Notification	

After the mapping was performed, all data to be used for demonstration purposes, related to the Teksid Aluminum real case (described in previous DA11.x documents) were entered, by using the SAP Transactions listed above. In total, some 200 *Equipments* were entered, representing product instances, production systems and their components (machines of different types, devices of different nature, details on workers employed in these production systems, etc.). To represent the attributes of these equipments, specific *Characteristics* grouped in *Classes* (one Class of Characteristics for each Equipment). Moreover, for each type of Equipment, a corresponding *Material* was also defined. Product structures (hierarchies of Equipment objects) were not defined, since in the demonstration case only one-piece products are addressed. On the opposite, appropriate Structures of Production Systems were defined and implemented, by exploiting the possibility to define hierarchies of Equipment objects. Finally, to some of the products and systems used in the demonstration, proper files were attached in form of *Document* objects, to be shown in the A11 PDKM GUI.

3.2 Structure of A11 java packages inside the PROMISE DSS

In the following, the implementation of the A11 DSS component, as one of the BOL modules of the overall PROMISE DSS system, will be discussed in details.

As it can be also found in other contemporary PROMISE documents, such as deliverable DR8.11, The PROMISE DSS was designed as a browser-based 3-tier architecture (Figure 9). For an explanation of the numerous advantages in future work and implementation provided by this kind of architecture, please refer to DR8.11.

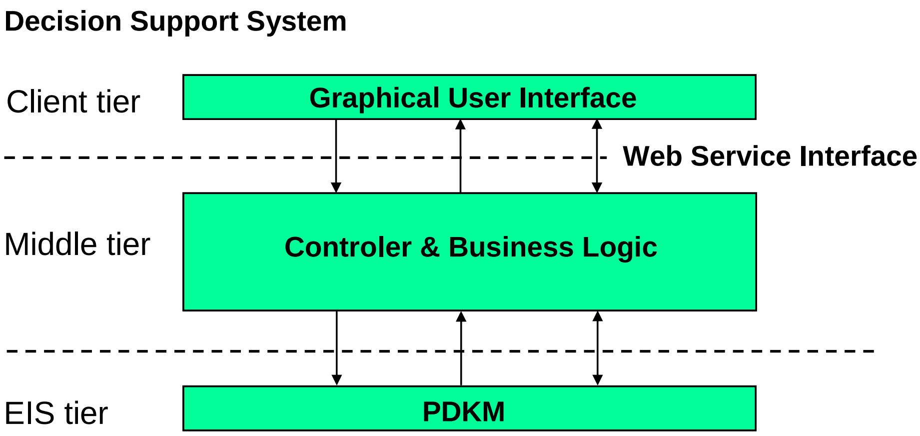

Figure 9: architecture of the PROMISE DSS

In particular (Figure 10), the middle tier implements the presentation logic, controller logic and business logic to control interactions between the application's clients and the application's data. The middle-tier controller logic processes client requests (such as DSS strategies) and retrieves data from the database. The middle-tier presentation logic then processes data from the application layer and presents the content to the client in form of JSPs and Servlets. The **controller-action** architectural pattern implements the Model Manager (one of the components of the PROMISE DSS).

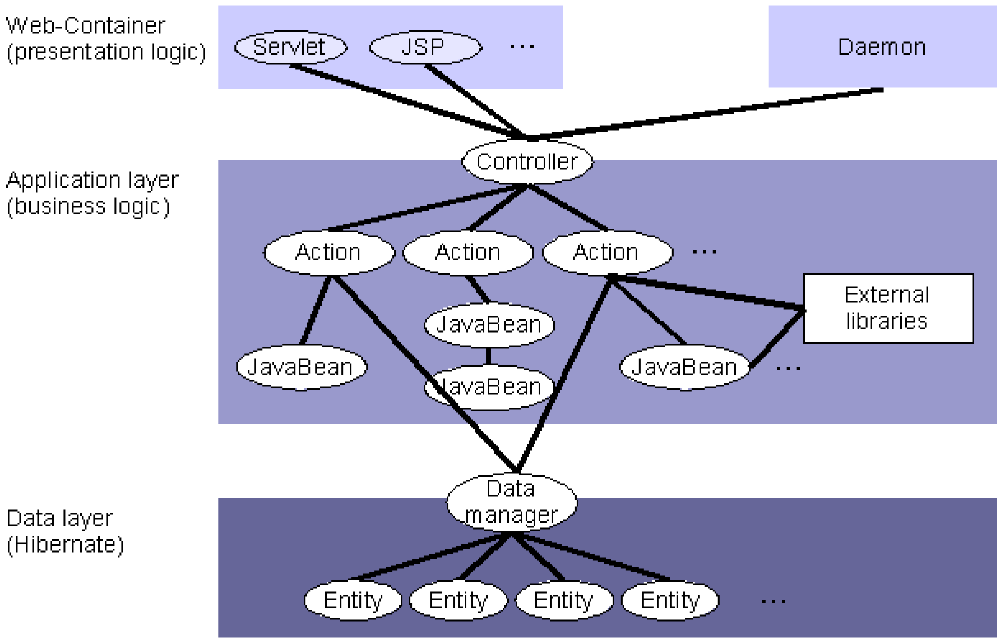

Figure 10: Architecture of the middle tier of the PROMISE DSS

The Model Manager in turn includes the algorithms supporting decisions in the different DSS application scenarios, one of which is A11.
The controller is the component handling actions taken by users or the daemon. The controller is always called by its method performAction(), which takes a String and an Object as arguments and returns an Object. The String identifies the action to be performed and the Object is used to pass user input and additional data to the action handler. Based on the action the user or daemon took, the controller uses a class named like the String that contains the business logic related to

the action. All action classes implement the interface Action which defines a method exec(). For further details, please refer again to DR8.11.

Generally, after the business logic has completed, the controller returns the results to the presentation layer in form of an Object. The presentation layer will then display them to the user. The decision strategies themselves are organized in form of **JavaBeans** components to provide reusable software components. Core beans may be combined to create function-specific JavaBeans which can also be linked against external libraries. The bean components are used to construct "intelligent" actions that fulfil specific functions (business logic).

Figure 11 below shows, with blue and white ovals, the JavaBeans of the A11 demonstrator, implementing the Action interface, as well as the Objects (one for each JavaBean, in black and white ovals) used to get input information from the Controller, after a request from the user (no daemon is implemented in A11 demonstrator), and also to store output information to be delivered to the Web-Container, again by interaction with the Controller. All these classes constitute the A11 **businesslogic** package of Java classes in the final overall PROMISE DSS.
A11 JavaBeans rely just on basic Java libraries, with no need of linking them to external specific-purpose libraries, as in the general case represented by the previous Figure 11.
Each of the A11 JavaBeans implements a related functionality of the A11 demonstrator, exactly those specified in section 3.3. For an explanation of the dynamical interactions between the end-user and the A11 demonstrator, for each functionality, please refer to section 5. Here, just the schematic mapping between the A11 JavaBeans and the related A11 use cases defined in section 3.3 is reported:

- **Quotation**, **TwoSystemsComparison**, and **OptimalBufferAllocationPrimal** JavaBeans implement the *Assess Product Modification* and *Assess New Product / Complete* decision-support functionalities of the What…If? Analysis set of functionalities
- **Quick Quotation** JavaBean implements the *Assess New Product / Quick-hit approach* decision-support functionality of the What…If? Analysis set of functionalities
- **Deterministic Setting** JavaBean implements the Optimal Reconfiguration (Deterministic Setting) decision-support functionality of the Optimal Reconfiguration set of functionalities

Figure 11 also shows that the A11 businesslogic package is connected to the **datatypes.a11** package of Java classes. This last package contains all Java classes (thirteen classes) representing the datatypes employed in the A11 demonstrator, and not shown in the previous Figure 11 (with the related links among them as well as with the classes of the businesslogic package) just for reasons of space.
Some of these classes offer non-trivial methods involved in the algorithms of the A11 scenario or representing the algorithms themselves; an example of these methods is the *physicalPerformanceEvaluatorLinearLayout* method, which evaluates the throughput of the production system (pieces/minute), and which actually implements one of the core algorithms developed during the project work: the Physical Performance Evaluator decomposition-based algorithm.

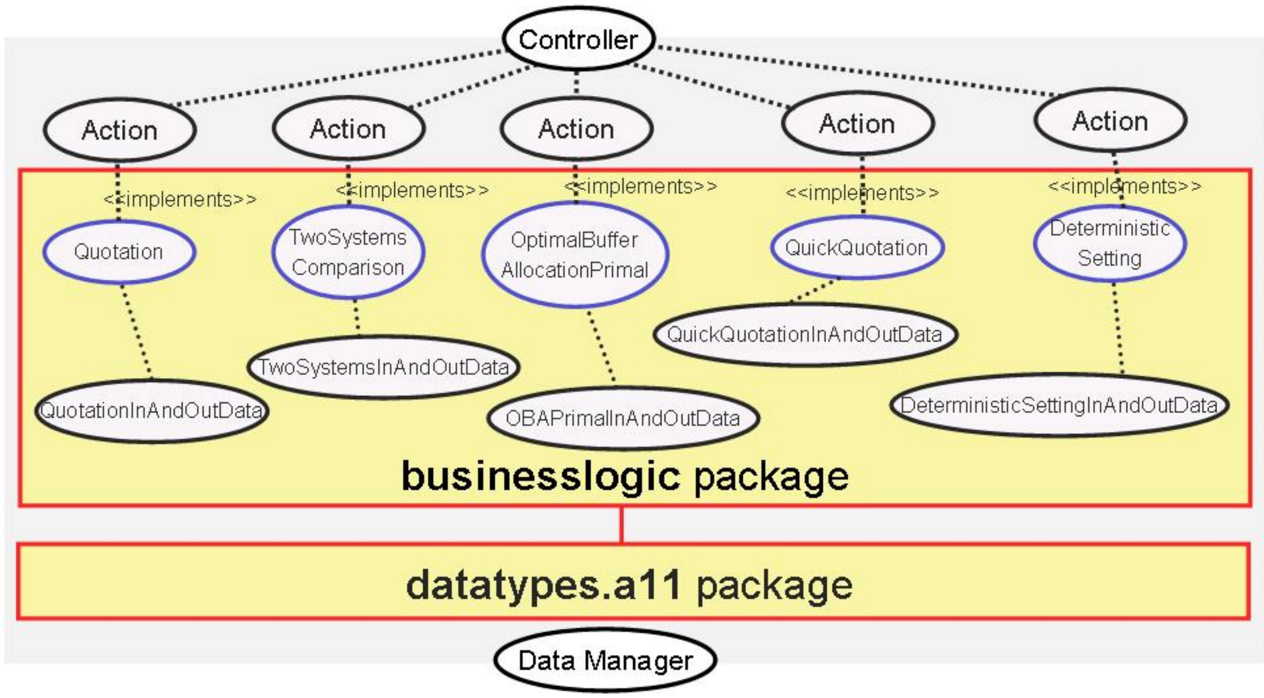

Figure 11: Structure of A11 JavaBeans and java libraries

The complete list of algorithms deployed by PROMISE WP A11 project work is reported in the next section 4.3. For each algorithm, a brief schematic description will be given. For a thorough explanation of the potential and of the computational performance offered by the different algorithms, please refer to material released for this purpose by WP R8, in particular DR8.11 document.

3.3 A11 Algorithms

The algorithms developed during the project have been the subject of a number of documents delivered in the context of WP R8 (the last one being DR8.11, where the different versions of these algorithms have been presented in detail). Here, just a summary of information on the same algorithms is sketched, in order to link each algorithm to the PDKM- and DSS-related functionalities presented in the previous pages.

3.3.1 Physical Performance Evaluator algorithm

Input	1. A production system, which can be: -already available in the A11 PDKM DB -created either from scratch (using a specific form in the DSS GUI) or starting from an existing system available in the same DB
Output	The set of physical performance of the production system under evaluation, i.e.: -the throughput of the system (pieces/minute) -the efficiency of the system (%) -for each material buffer, the average number of pieces present -for each working station, the percentage of time for which the station is “up and running” (i.e. working, producing), the percentage of time for which it is down (i.e. failed), and the percentage of time for which it is inactive (i.e. blocked or

	starved)
Developed during PROMISE (YES/NO)?	YES.
Teksid Aluminum – specific (YES/NO)?	NO. It works for all discrete manufacturing production systems (both single-product and multi-product) showing a "classical" linear layout, with a series of tandem working stations, divided by a number of material buffers, and where each station is composed of a number of identical machines working in parallel.
Mathematical technique	Discrete Time / Finite State Decomposition algorithm, based on a markov-chain modelling approach of working stations and material buffers in the production line

3.3.2 Economical Performance Evaluator algorithm

Input	1.A production system, which can be: -already available in the A11 PDKM DB -created either from scratch (using a specific form in the DSS GUI) or starting from an existing system available in the same DB 2.The yearly demand of the product(s) produced by the production line under evaluation
Output	The set of economical performance of the production system under evaluation, i.e.: -the yearly production volume (pieces/year) -the eventual production quantity to be externalized (pieces/year), because of shortage problems -the yearly operating costs (euro/year), i.e. the costs for running and maintaining the system -the investment costs (euro), with the related break-down in the investment costs for each machine/buffer/etc. -the unit production cost (euro/piece)
Developed during PROMISE (YES/NO)?	NO. Available from well established literature in the economic field.
Teksid Aluminum – specific (YES/NO)?	NO. It works for all discrete manufacturing production systems (both single-product and multi-product) showing a "classical" linear layout, with a series of tandem working stations, divided by a number of material buffers, and where each station is composed of a number of identical machines working in parallel.
Mathematical technique	Basic state-of-the-art cost-accounting techniques.

3.3.3 Optimal Buffer Space Allocation algorithm

Input	1.A production system, which can be: -already available in the A11 PDKM DB -created either from scratch (using a specific form in the DSS GUI) or starting from an existing system available in the same DB 2. A constraint regarding one of the following (mutually exclusive):

	-the minimum throughput (pieces/minute) the system must satisfy -the maximum space available to be allocated to material buffers
Output	The optimal configuration of buffers (maximum number of pieces each buffer must be able to store)
Developed during PROMISE (YES/NO)?	NO. Available from well established literature on optimal buffer allocation.
Teksid Aluminum – specific (YES/NO)?	NO. It works for all discrete manufacturing production systems (both single-product and multi-product) showing a "classical" linear layout, with a series of tandem working stations, divided by a number of material buffers, and where each station is composed of a number of identical machines working in parallel.
Mathematical technique	Continuous State Buffer Space Allocation Optimization

3.3.4 Quick Quotation algorithm

Input	A few pieces of information on the product whose unit production cost must be estimated. This description can either already exist in the PDKM DB or be directly entered by the user and regards the overall finishing level of the product, the overall cleanness level, the overall tightness level, the estimated yearly production volume, the material, the country of production, and obviously the product type (e.g. cyclinder head)
Output	The estimated unit production cost (euro/piece)
Developed during PROMISE (YES/NO)?	NO. Available from literature on regression Analysis
Teksid Aluminum – specific (YES/NO)?	YES. It works for a sub-set of Teksid Aluminum products: cylinder heads, cylinder blocks, camshaft carriers.
Mathematical technique	Linear regression

3.3.5 Dynamic Programming Optimization of system configurations

Input	1.A field-data-based product evolution scenario, with the specifications of one or more variants of the same product, and even new products to be added; these can be: -already available in the A11 PDKM DB -created either from scratch (using a specific form in the DSS GUI) or starting from an existing system available in the same DB. These specifications are based on just the most important product features, called in the context of A11 demonstrator after the name of Product Functionality 2.One or more production systems, with the specification of the related production processes, which the Machining Platform Personnel either specify directly or take from the PDKM DB These specifications are also based on just the most important

	features of the production system and process, called in the context of A11 demonstrator after the name of System Functionality
Output	1.The optimal reconfiguration strategy (sequence), for each possible evolution of the product 2.All the economical details on each possible sequence of reconfigurations, which is basically represented by the resuls provided by the Economical Performance Evaluator, for each product/process/system and for each year. All details on the change from one configuration to another are also given
Developed during PROMISE (YES/NO)?	YES. This represents an enhancement of the state of the art on production system design.
Teksid Aluminum – specific (YES/NO)?	NO. It works for all discrete manufacturing production systems (both single-product and multi-product) showing a “classical” linear layout, with a series of tandem working stations, divided by a number of material buffers, and where each station is composed of a number of identical machines working in parallel.
Mathematical technique	Discrete Time / Discrete State Dynamic Programming

4 Demonstration of A11 scenes

4.1 Scene 1: Assessing the unit product cost of a field-data driven product modification

First, the user, must start the PROMISE PDKM/DSS, and then select on the top left the A11 POLIMI BOL demonstrator. This makes the following window to appear (Figure 12), which contains the main menu of the A11 DSS, with the two buttons named “What…If? Analysis” and “Optimal Reconfiguration”.

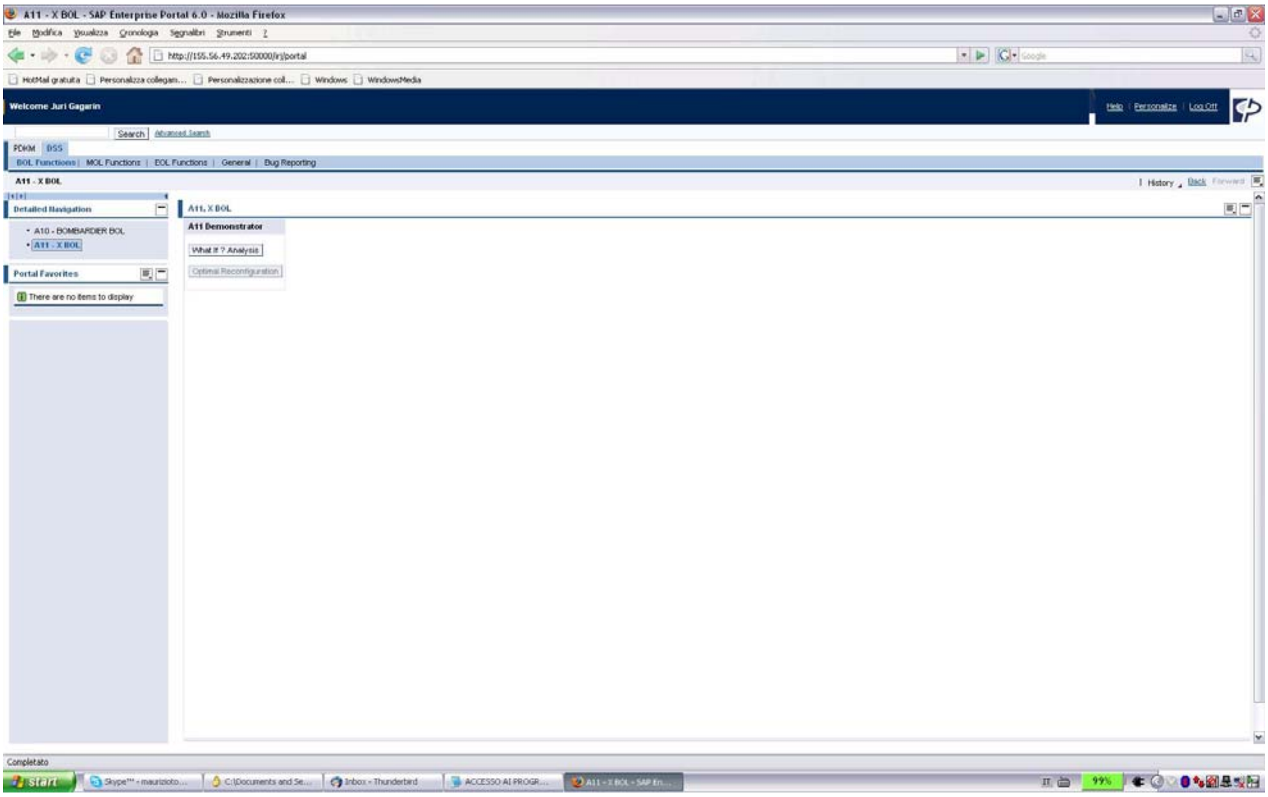

Figure 12: Starting the A11 DSS demonstrator (POLIMI BOL)

Then, after clicking on the “What…If? Analysis” button, the menu in Figure 13 appears. The window related to each voice of the menu can be enlarged by clicking on the white rectangle on the right. The first three voices of the menu (Quotation, Comparison of System Alternatives and Optimization of System Configuration) are used throughout Scene 1.

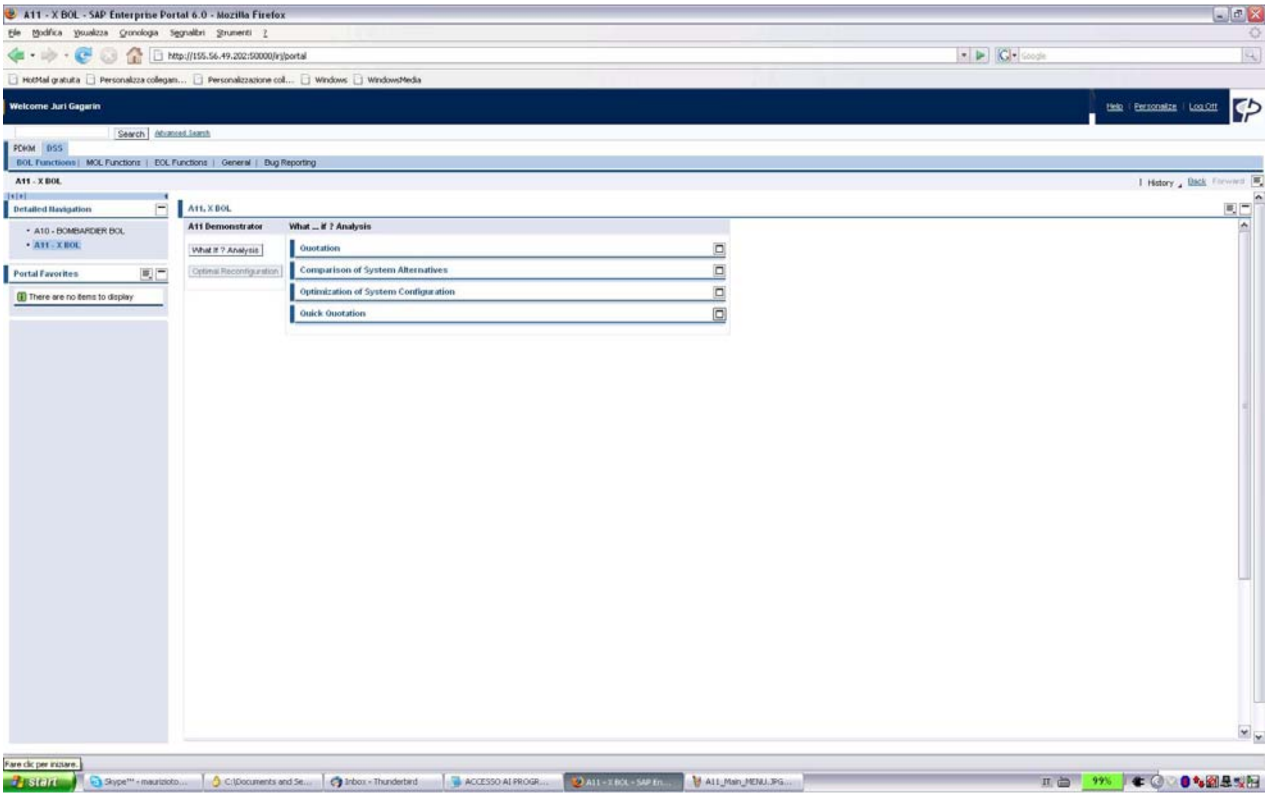

Figure 13: Menu of the ”What...If? Analysis” decision-support functionality

By enlarging the Quotation window, the user can specify the following information (Figure 14) on the field-data-based product modification to be assessed:

- The number of years for which the modified product has to be produced. After an integer number is entered here (seven, in the case shown in Figure 14), a corresponding number of “ Year *i* ” windows appear (in or case, it is *i* = 1,2,…7). In each window, the user either selects from the PDKM DB or inserts directly by using a proper form, the needed information on the product, its modifications to be assessed, and the configuration of the production system to be used for producing the modified product (see further on for details), as well as the forecasted product demand.
- The externalization price (euro/piece) that must be paid for each product unit of the modified product in case of “shortage”, i.e. in the case the production system configured/adapted to implement the product modification cannot satisfy the requested product demand (see further on).
- The rework unit cost (euro/piece), to be incurred for each product unit not passing the quality controls at the end of the production line, which must be generally reworked manually by the proper personnel.
- The unit hourly energy cost (euro/h), for each kW of power of the devices building up the considered production line. This is strictly dependent from the country of production where Teksid Aluminum investigates to possibly produce the modified product. Generally, when dealing with field-data-based product modifications, the country of production is already decided and coincides with the country where the existing production line already produces the current version of the product. Anyway, when dealing with the assessment of a new product possibly to be produced (Scene 2), the country of production becomes one of the decision parameters and, given the actual costs of the energy in different continents and countries, can greatly affect the final unit production cost.

- The capital cost of the investment (%), which is decided at the corporate level, with respect to the investment under study, and which is already decided, in case of assessment of product modification, and to be decided in case of assessment of new product (Scene 2).

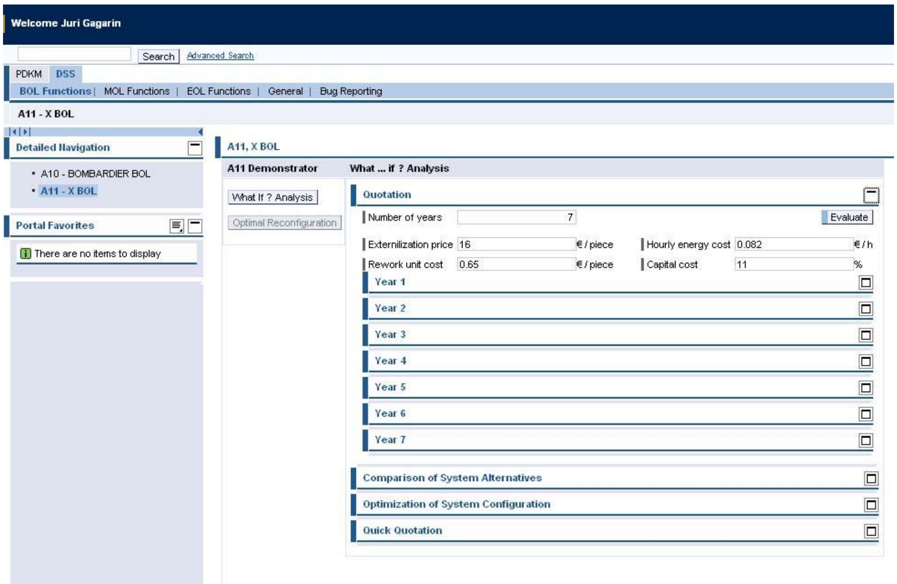

Figure 14: Defining the field-data-based product modification to be assessed

By enlarging the window related to each year, the user can enter/select specific data for the related year in the planning time horizon. For example, enlarging the window related to Year 1 (Figure 15), the user first enters the yearly production volume (pieces/year) for the same year.
Then, the user also selects the product type describing the modified product from the PDKM DB, if this was already entered manually, or can also define at the moment the product under evaluation and the modifications to be implemented. In the second case, the modified product is also saved into the PDKM DB. To be noted that different possibilities are available to the user, who can either enter a modified product remaining equal all along the planning horizon, or also enter/select different sequences of product modifications, as needed and anyway based on what is known from the customer and in turn derived from the data collected in the field.
Finally, the user selects, from the PDKM DB, the production system configured/adapted to accomplish the product modification at the shop floor level. This is the case when the production system was entered previously in the same DB. If this is not the case, the user can specify at the moment the configuration of the production system to accomplish the product modification defined above, and the defined system configuration must be saved into the PDKM DB before starting the computation. All the details on the considered production system (either selected from existing configurations or defined for the specific purpose) then appear in the bottom part of the "Year 1" window. The table shows the composition of the system in terms of machines, buffers, operators, etc. By clicking on one or more of these system resources, all the details on them can be viewed (they are retrieved from the PDKM DB).
On the point of "how to choose/configure the right production system to be put into each year's window", please see further on this section.

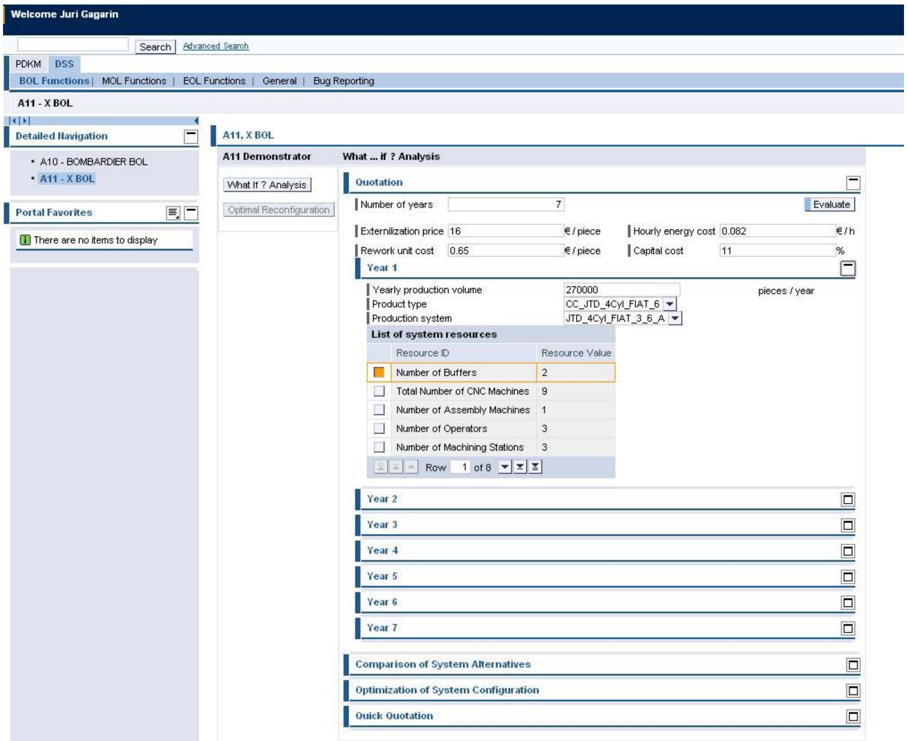

Figure 15: Specifying data for each year of the considered horizon

After all needed data have been either entered or selected from the PDKM DB, the user can click on the "Evaluate" button, in the top-right of the Quotation window. By doing this, the DSS algorithms of the Assess Product Modification functionality are called, for each year of the considered sequence of product modifications, of system configurations, and of demand forecasts. After the time required for computation, the results are displayed as in Figure 16. The complete list of available results is reported in the following:

- The Net Present Value (top left of the figure) of the investment related to the product modification (in euro currency, not including the revenues coming from selling the modified product)
- Four graphs, in particular, in clockwise order starting from the one in the top left:
  - The unit production cost of the modified product (euro/piece), for each year of the considered planning time horizon. The histogram is very important, since it shows if and how much the unit product cost, considering both internal and externalized production, changes over time. This in turn is useful for the commercial staff when preparing the Final Offer with the proposal of the price to the customer.
  - The investment costs (euro), for each year of the considered planning time horizon. In the case shown in Figure 16, since the product, once modified, is supposed to never change in the rest of the planning horizon, the investment in the adaptation of the production system, also not changing from period two to period seven, is concentrated in the first period.
  - The overall cumulative value of the Net Present Cost for each year of the planning time horizon, also considering revenues derived from selling the product. The histogram obviously shows positive values in the first periods, and then negative values in the last periods (they are "costs minus revenues" !). This helps the user to estimate the payback time of the investment under assessment, as well as the full sequence of cash flows. To be noted that the ordinate value of the last vertical bar of the histogram corresponds to the Net Present Cost already discussed above.

- The quantities (pieces) produced internally (blue histogram), i.e. by means of the defined production systems, in each year, as well as the quantities (pieces) externalized (purple histogram), in case of shortage, also in each year. This is very important since the Machining Platform knows in advance in which years of the planning horizon the need of outsourcing should be expected, and for which quantities.

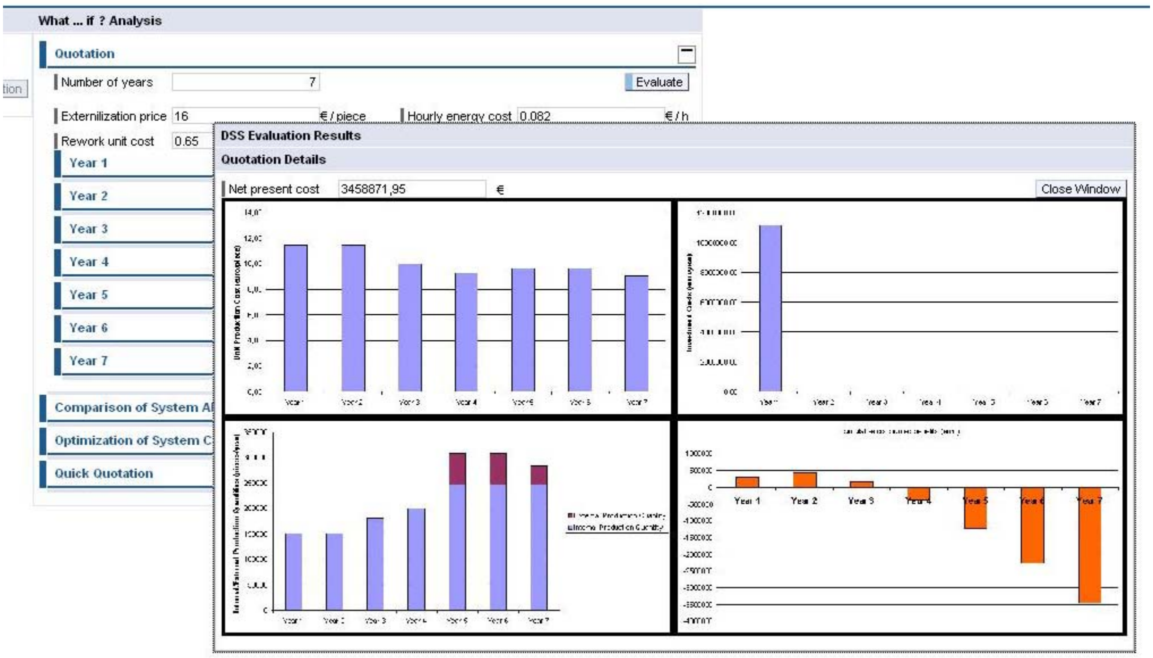

Figure 16: Results of the assessment of the product modification in the considered example

Finally, it can be shown how the user is able, by interacting with the A11 demonstrator, to:

- define different system configuration alternatives to possibly be selected for implementing the product modification
- perform different optimizations of each of these system configurations
- compare the different system configurations entered and optimized for each of the considered product modifications in the planning horizon, and choose the best one, in ordered for it to be selected for the computation shown above

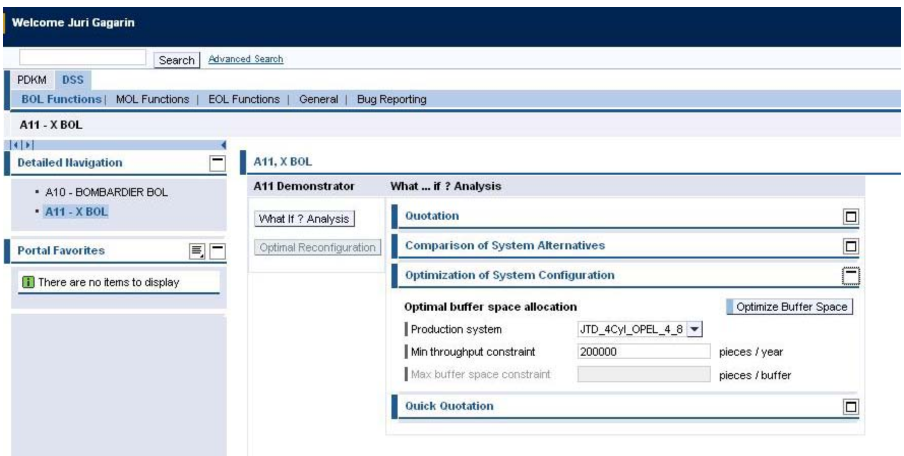

Figure 17: Optimizing the buffer space allocation in the Teksid Aluminum JTD line

For each system configuration, the user can perform different optimizations in order to improve the system configuration as it best fits to the different product modifications that must be assessed. To do this, the user enlarges the Optimization of System Configuration window, where one or more optimization-support functionalities are present and can be selected.
For demonstration purposes, just a buffer allocation optimization functionality was implemented, but it is useful to notice here that, in principle, any decision-support functionality (and the related algorithms) dealing with economical or performance optimizations of the production system configuration, including the process cycle (with its processing parameters) implemented in the same production system, can find room here, as far as they are concerned with the specific needs of the real case where the A11 Adaptive Production demonstrator is applied.
In the implemented buffer allocation optimization functionality, the user will first select the production system from the PDKM DB (Figure 17), where the same configuration could have been either just entered (either starting from scratch or based on a previously existing configuration) and saved, or could already exist in the DB and it is selected as it was.
Then, the user can specify one out of two mutually exclusive decision constraints, i.e.:

- the minimum throughput (pieces/year) that the production system must meet
- the maximum buffer space (pieces/buffer) that can be allocated for each buffer; this second constraint is related mainly to space availability problems in the shop floor or to the maximum number of pieces that can be allocated in a commercially available buffering system (if the buffer have to be selected from commercially available products)

After having introduced this input set, the user just has to click on the Optimize Buffer button, in the top-right of the same figure, and then wait for the results, which are displayed as in Figure 18.

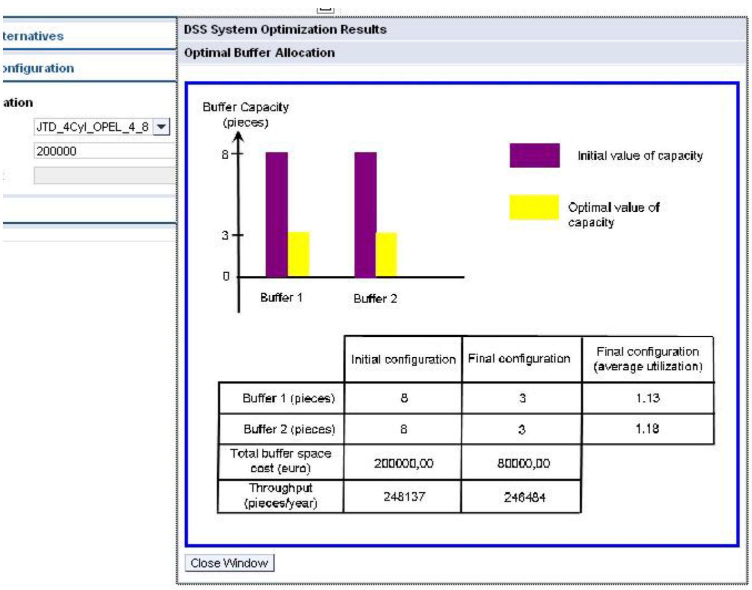

Figure 18: Optimization results in the case of the JTD production line

The results of the buffer allocation functionality are composed of the following:

- a diagram, showing, for each buffer in the system:
    - the initial value of capacity (pieces) in each buffer, i.e. the maximum number of pieces that the buffer can store, as the buffers are configured in the selected system (purple histogram)
    - the optimal capacity (pieces) in each buffer, provided by the computation, so that the overall costs are minimized, the system throughput is maximized, and above all the constraint inserted by the user is met

- a table, showing:
    - the numbers represented by means of the bars in the histogram
    - the average utilization of each buffer, as it is expected if the system will be operated in the optimized configuration
    - the total cost of each buffer
    - the throughput that must be expected if the system will be operated in the optimized configuration

In the case of Teksid Aluminum, the buffer allocation optimization functionality was chosen, among the optimization functionalities possibly to be implemented, because it represents one of the main issues in their system design/adaptation problems.

Typically, buffers are chosen by the Machining Platform Personnel “from the shelf”, without ay kind of optimization, basically relying on the offers of buffering systems providers, without any tool to check for the economical viability of what is offered. This has lead many times, such as in the JTD production line, to have situations like the one shown in Figure 17 and in Figure 18, where buffers of 20 k€ (with capacity equal to 8 pieces) each have been bought and implemented, instead of smaller (and more than sufficient) buffers of 80 k€ each (with capacity equal to 3 pieces). Please note that, though the “200 k€ buffers” is greater than the one of the “80 k€” buffers, the throughput of these last is anyway much higher than the minimum throughput required by the user (200000 pieces/year), and the difference with respect to the throughput constraint is also much higher than any yearly product demand increase that could be expected for the product under consideration. Thus, the buffers in the production system have been oversized without ant need, and what is even worse is that this has resulted in a sensible increase in the overall investment cost related to the JTD production system.

One last not no the optimization functionality shown above: the table of results also shows the average utilization of each buffer, i.e. the average number of pieces in each buffer in a generic time instant, as it is expected if the system will be operated in the optimized configuration. The availability of this information is very important for the final user: in the specific case, this information tells that in each generic time instant, each of the two buffers in the line needs only room for more than one piece and less than two pieces, which means in practice that a buffer of two-pieces-size would be sufficient for the investigated configuration to meet the minimum throughput requirement; anyway, the minimum buffer space allocated in this case was set equal to three, since the smaller buffering systems available on the market for applications related to Teksid Aluminum products is exactly equal to three (also, since the average numbers in the table are averages, it is a good choice to oversize a little bit the buffer capacity). The optimization algorithm thus can also take into account market constraints of such nature.

As a last point, please note that the algorithm implemented for the optimal buffer allocation functionality is not Teksid-specific: thus it can also be re-used as-is for any kind of discrete manufacturing production system having a linear layout (transfer lines, flow lines). Also the benefits discussed above are also of a very general kind and common to discrete manufacturing applications.

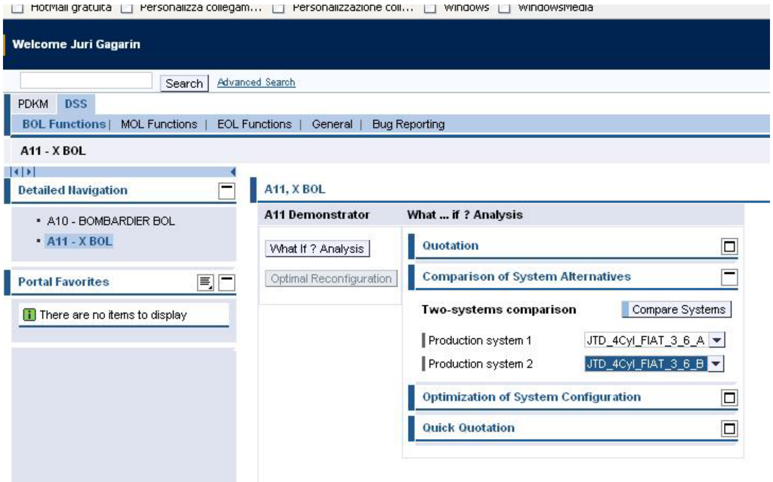

Figure 19: Comparing different system configuration alternatives

Now, having had the possibility of creating many different system configurations, having optimized them by means of a number of optimization-support functionalities, and having saved all these system configurations into the PDKM DB, the user can now use the Comparison of System Alternatives functionality. This is called to compare the different configurations and to find, for each product modification and each year of the planning horizon under investigation, the system configuration that best fits the needs of the product modification and yearly production volume, select it and then assess it in the context of the Quotation functionality.

To do this, the user enlarges the Comparison of System Alternatives window, and finds a number of functions to compare the system configurations.
In the context of this demonstration, the Two Systems Comparison (Figure 19) function was the only one implemented, in order to prove the concept behind the usefulness of such a functionality. Ideally, here the user would find different comparison functions based on:

- the number of system configurations that must be compared
- the parameters subject to the comparison

This functionality is very simple to use: the user just selects the systems configurations that must be compared (Figure 19), and in future implementations also the number of parameters that must be compared, and then clicks on the Compare Systems button, then waiting for the results.

These results are then displayed as in Figure 20, where for each system configuration the following pieces of information are presented:

- the average efficiency/availability (in %) of the production system over time
- the average production rate (throughput), in pieces/year
- a graph, showing, for each working station in the production system:
    - the percentage of time for which the station is “up and running” (i.e. working, producing), by means of the blue histogram
    - the percentage of time for which it is down (i.e. failed) , by means of the purple histogram
    - the percentage of time for which it is inactive (i.e. blocked or starved), by means of the yellow histogram

The comparison, in this case, only regards the physical performance set of the configurations being compared, and calls, for each of them, the Physical Performance Evaluation algorithm, but could also, in future implementations, quite easily take into account economical performance indicators (e.g. euro/piece of full production cost): the modification of the algorithm should be carried out based on the specific needs of the specific implementation of the A11 Adaptive Production demonstrator. One important feature would be that the user should have also the possibility to choose how many and which of the possible comparisons to carry out, directly by selection from the GUI menu of the Comparison of System Configurations functionality.

Figure 20: Results of the comparison between two system configurations in the case of the JTD production line

4.2 Scene 2: Assessing the unit product cost of a new product whose business can be acquired

This second scene can happen in one of the following two mutually exclusive ways:

A. There are sufficient time and pieces of information to carry out the Assess New Product / Complete use case. In this case, the assessment is carried out in the same way as in Scene 1 above, but with respect to a new product type, which is entered into the PDKM DB before being assessed.

B. The are not sufficient time and/or pieces of information to carry out the Assess New Product / Complete use case , and thus the Assess New Product / Quick-hit approach use case must be carried out.

Concerning point A, there is nothing particular to be added to what was already written for Scene 1 above: input and output screens are exactly the same in the two cases, as well as the benefits brought to the decision maker.

Concerning point B, the user/demo interactions can be described as in the following. The user first clicks to enlarge the Quick Quotation menu (Figure 21), then he either selects a product from the PDKM DB, which contains just the few basic pieces of information available on it, or enters directly in the GUI the same available pieces of information, which can be gathered e.g. from an e-mail received from the potential customer, and by which the same customer requests the quotation to Teksid Aluminum. In the former case, the fields are automatically filled in by the software, by means of proper queires to the PDKM DB. In both cases, only the Price field is left blank.

After clicking on the Evaluate Price button, the decision support algorithm is called and then, after the required computational time, the results are displayed by filling in the Price field (euro/piece).

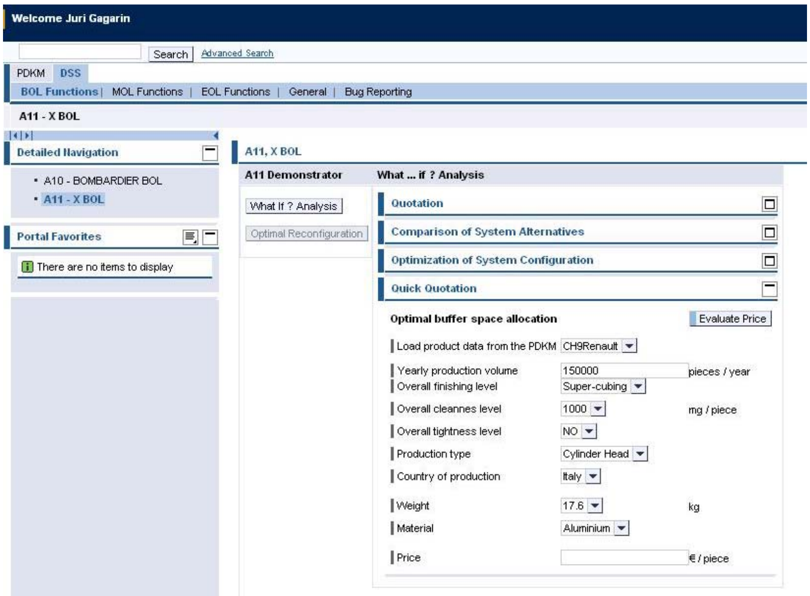

Figure 21: Quick quotation of a cylinder head

This functionality (“Assess New Product / Quick-hit approach”) is very important for the user, though it not strictly in one-to-one relation with field data of the product under evaluation.
This importance is given by the fact that, if Teksid Aluminum manages, by this possibility of having a quick but precise evaluation of the unit production cost and then of the price to be requested to the potential customer, to bring the business related to this product “in the house”, then this new business will, with any probability, result in future needs of assessing the inevitable modifications the product will have to undergo. These will be managed by the Quotation, Comparison of System Alternatives and Optimization of System Configuration as in Scene 1.

The same would hold for sure also for the “Assess New Product / Complete” functionality: the first problem remains that of getting new business, by supporting as quickly and as precisely as possible both the system designers and the commercial staff. Only if the business is brought “in the house”, there will be the need of assessing field-data-based modifications.

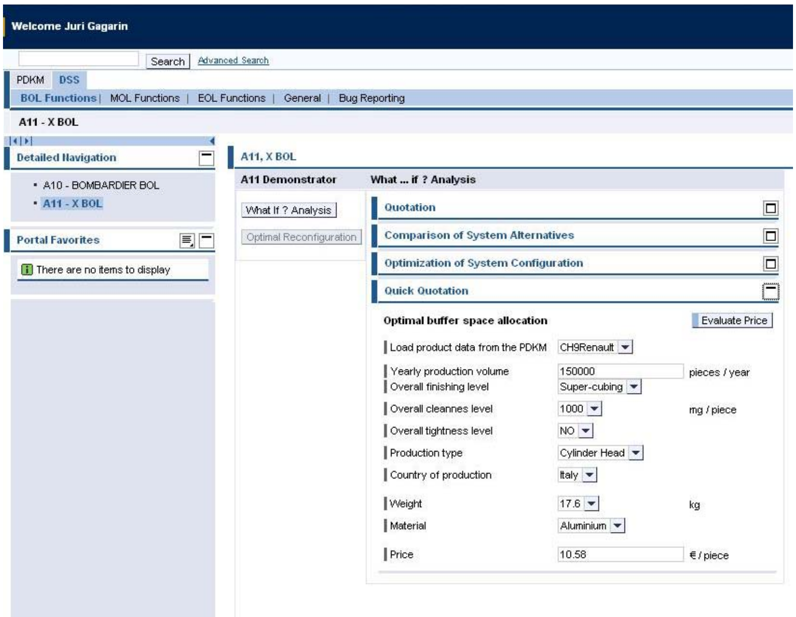

Figure 22: Results of the quick quotation in the considered case (cylinder head)

4.3 Scene 3: Searching for the optimal reconfiguration policy in a field-data-based scenario approach

Sometimes, starting from field data, it is possible to derive proper scenarios and the related links among them. These scenarios are obviously product scenarios, taking into account one starting product configuration, with its yearly demand forecast and its technical details, as well as its evolution over time, with modifications of the starting product configuration, and the possibility of adding/deleting product variants, each with the related demand forecast and technical details.

This scene is important for Teksid Aluminum, and OEM suppliers in general, when the collaboration with the OEM is sufficiently deep that the information on possible (field-data-based) product evolutions is available, but is even more important for the OEM themselves.
In fact, product designers are able, by using this functionality together with system designers (and in relation to production stages which are managed internally by the OEM), to assess different field-data-based product improvements they have in their mind, and consequently assess the impact this field-data-based product improvements have on these production stages, in the PROMISE closed-loop PLM approach.

First, the user clicks on the Optimal reconfiguration button, in the starting menu of the A11 Adaptive production software demonstrator. This opens the window represented in (Figure X[1]-to be added Monday, June 9th).

In its top portion, this window is very similar to the one shown as the starting window of the Quotation functionality discussed with respect to Scene 1, the only difference being that the additional information concerning the budget constraint to be met in reconfiguring the production system (top-right of the window). This last information is fundamental in this case, as it will become clearer later on.

Then, the decision support is carried out in three sequential steps:

- Step 1. The field-data-based product scenarios to be considered are entered.

- Step 2. The system configurations to be considered to produce the product previously entered in the field-data-based scenarios are entered.
- Step 3. Computation is started, and the related results displayed.

Step 1

First, the number of product scenarios one wants to consider is typed into the corresponding field. Then, by enlarging the Display/Modify product scenario number" window, after having entered an integer between 1 and the number of scenarios considered, the window in (Figure X[2]-to be added Monday, June 9th) opens. Here, the user inserts the number of products in the considered scenario, the year of the planning horizon when the product scenario happens/could happen, and then selects from the PDKM DB (or enters directly in the PDKM DB) the products to be considered, as well as the demand forecast for each of them.

Then, clicking to enlarge the "Create product evolution graph" window, the window in (Figure X[3]-to be added Monday, June 9th) opens. Here, the user selects, for each scenario, which scenario is connected to it in the following year of the product scenario graph (more in general; it has not be a scenario tree), thus giving the scenario graph the proper structure. To check if the proper scenario graph the user has is mind is being created, the same user can click on the Display graph button, which opens the window shown in (Figure X[4]-to be added Monday, June 9th).

By repeating these sub-steps the needed number of times, the user enters/modifies the pieces of information on the field-data-based product scenarios, and finally moves to Step 2.

Step 2

Here, the user first selects one of the scenarios in the field-data-based scenario graph just created, and also selects one product in the scenario. Then, by enlarging the "Product Functionality Summary" immediately below, the window in (Figure X[5]-to be added Monday, June 9th) appears. This window shows to the user all pieces of information, retrieved from the PDKM DB, which mostly impact on the requirements the system configuration chosen to produce the same product in that specific scenario has to meet. In the Teksid Aluminum case, these pieces of information are:

- Number of cylinders: 4, 5, etc.
- Finishing Level: Cubing(C), Roughing (R), Super-cubing (SC), Finishing(F)
- Yearly production volume (pieces/years)
- First version of the product type: YES, NO
- New (i.e. if it is a new product just added to the production line): YES, NO

The list above, as a whole, is called Product Functionality, and the corresponding (list of) features of the production system being in a one-to-one relation with the Product Functionality is called System Functionality.
In other cases, different Product Functionalities could be defined, as long as the pieces of information in the list are retrieved from the product features present in the PDKM DB.

After having browsed the Product Functionality specification for the considered product in the considered scenario, for each product in each scenario, the user defines the number of system configurations to be considered in the assessment process.
After that, the user enlarges the "Display/Modify system configuration number" window (Figure X[6]-to be added Monday, June 9th). Here, the user selects (or enters directly) the name of a system configuration, whose related System Functionality is retrieved from the PDKM DB and then

displayed in the fields from “Number of OPs” through “Type of MHS”. In addition, the user states if the considered system configuration must be used to produce all products in the considered scenario, or alternatively which are the products this system configuration must produce. For each of these products, the user can select one out of the many (if many exist) different versions of process (manufacturing) cycle, or alternatively can enter a new process cycle by compiling a corresponding form.

The user is now ready to proceed to the next step.

Step 3

Here, the user first selects one scenario from the graph created before. This scenario is the current scenario. Please note that as soon as the user gets field-data-based information on potential modifications to be applied to the graph, she/he can repeat the steps above and specify/modify the related information, so that the scenario graph is always up-to-date.
So, after having selected the current scenario, the user can access all the details on it, by clicking on the “Show details” button immediately below (only the detail on the number of production system configurations in the scenario is shows in a related field, for the rest of the pieces of information on the scenario the button must be clicked).

Then, as soon as the user knows exactly which is the next product scenario, which could be either one of the scenarios in the current graph or a new one to be introduced into it, she/he can proceed with this step. Please note that at a certain point in time, the information on which will be the next product scenario, i.e. on how many and which products will have to be produced in the next period (e.g. year) is known for sure, at least from the customer’s orders.
Now, knowing the next product scenario, shown on the bottom-right portion of the window, the user can browse the information on it, by clicking on the “Show details” button immediately below. The only field left blank for the moment is the “Number of systems” under the “New product scenario” field. Here, the number of system configurations corresponding to the optimal setting of production systems to produce the product(s) in the specified next scenario will be displayed, after the user has clicked on the “Compute” button. This button calls the optimization algorithm, which finds out which is the best system configurations, among those specified before, considering the current scenario and system configuration, the next scenario and all potential scenarios in the graph following the next scenario.

Finally, by clicking on the “Display graph” button in the bottom-right of the window, the graph in (Figure X[6]-to be added Monday, June 9th) is displayed onto the GUI.
This graph shows, for every possible system configuration meeting the production requirements of the specified next product scenario, the related Net Present Cost, from the next period (i.e. from when the next product scenario will happen) to the last period in the planning horizon. Also, the graph shows the Net present Cost related to the typical configuration that the user would configure and buy, if this functionality of the A11 demonstrator was not available, which corresponds to the typical and much oversized and flexible configuration that production system providers would presently sell to the user. Please note the difference (in millions of euro) revealed by applying this functionality to the shown case, which is the one of the JTD production line and products.

4.4 Scene 4: Browsing through products, production processes and systems in the PDKM DB

This last just has the purpose of showing some of the many PDKM-related functionalities of the demonstrator, as well as the integration between the DSS and the PDKM components of the A11 Adaptive Production demonstrator. The user first accesses the PDKM “Welcome Page” (Figure 23).

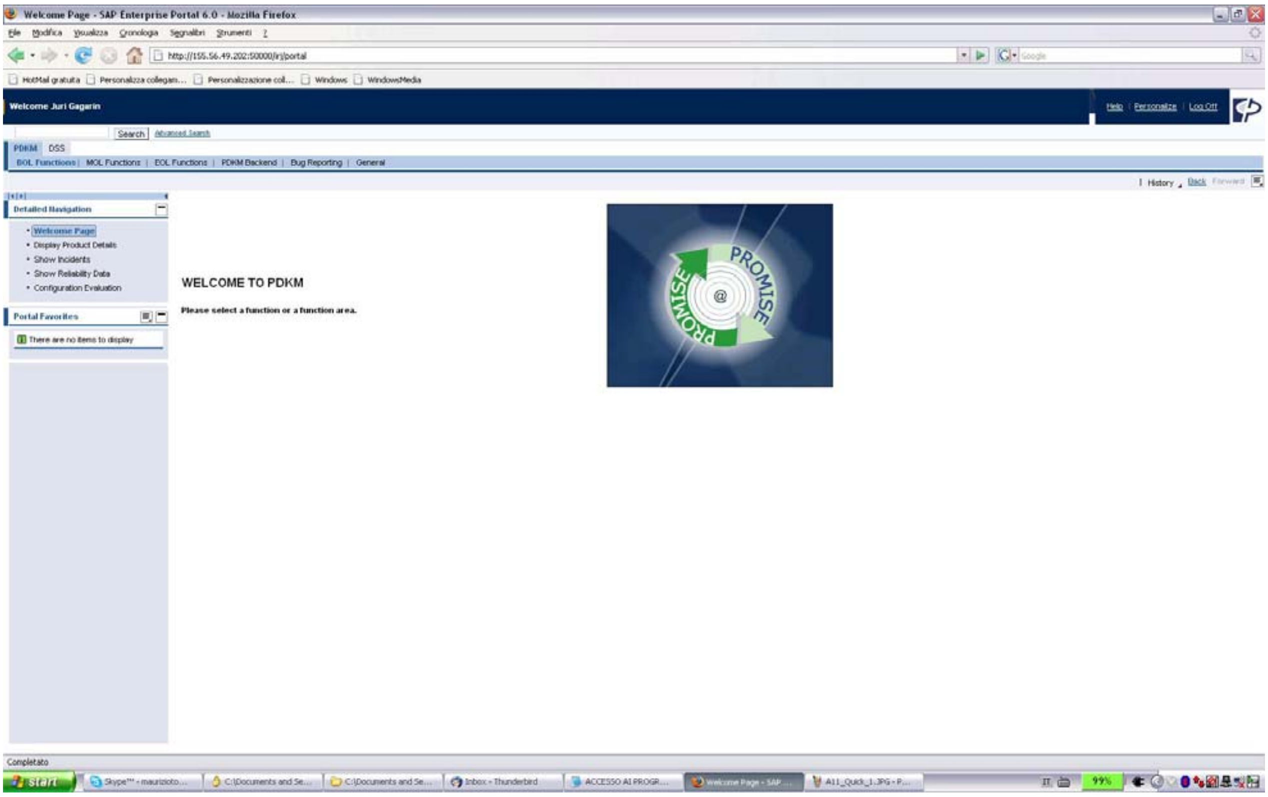

Figure 23: ”Welcome page” of the PROMISE PDKM

Then, the user selects the “BOL functions” menu, and clicks on the “Display Product Details” in the “Detailed Navigation” window (top-left portion of the screen). Then, by using the Search functionality provided by the PDKM (top-centre portion of the “Display Product Details” window), the user can browse any pieces of information presently part of the PDKM DB for the A11 Adaptive Production demonstrator.

In the following, some of these browsing capabilities will be shown.

For instance, the user can browse the information on all the product types in the PDKM DB. In the Product List window (top-left of the screen, Figure 24), the user finds all the Materials (in the SAP ECC 5.0 terminology), and after selecting one of them, he can also see:

- The list of Equipments (again in SAP ECC 5.0 terminology) being instance of the selected Material (middle-right of the screen, in the Product Statistics window)
- The generic pieces of information on the selected material (bottom-centre of the screen, in the Product Details window)

These Materials represent Teksid Aluminum’s products, production systems, machines, operators, material handling devices, etc.

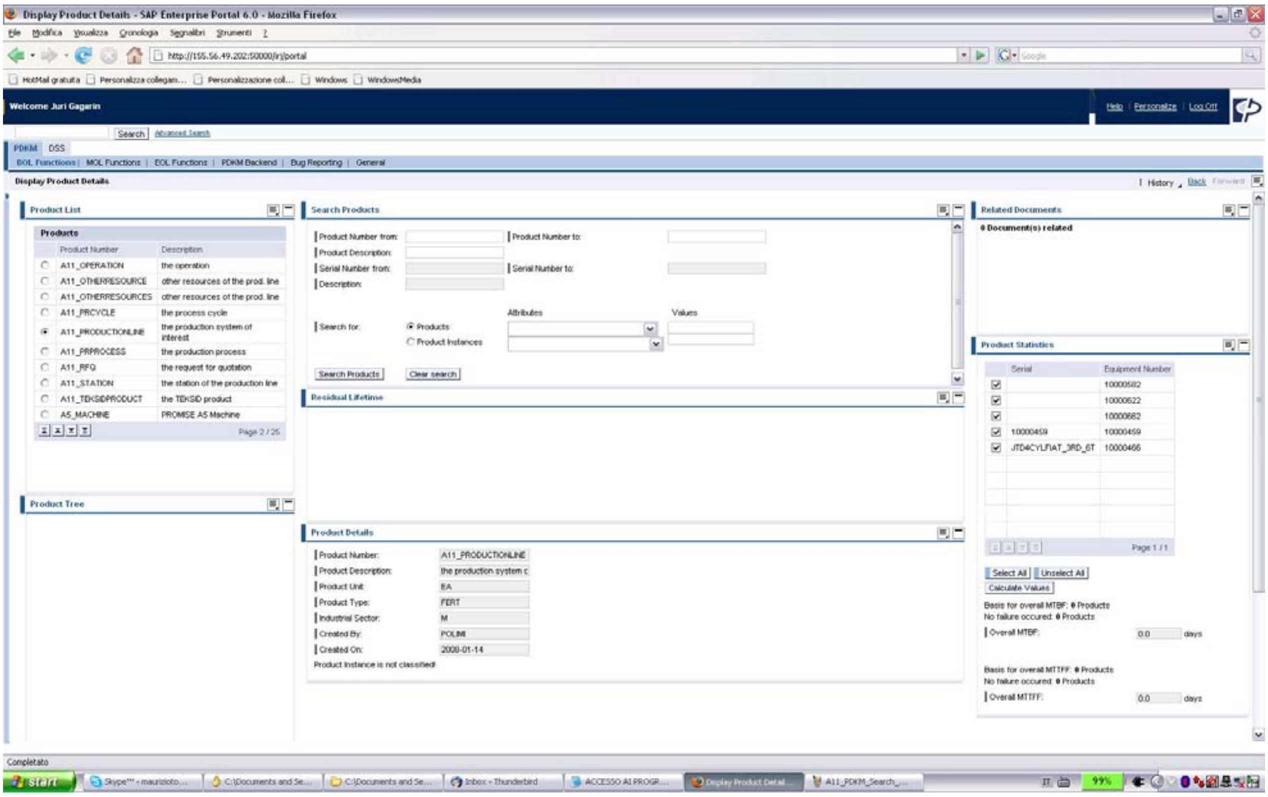

Figure 24: Browsing through A11 "Materials"

By using the same search functionalities of the PDKM software component of the demonstrator, the user can also browse through all the Equipments currently in the PDKM (Figure 25). These Equipments represent, exactly as the related Materials, Teksid Aluminum's products, production systems, machines, operators, material handling devices, etc.

The main differences, with respect to the browsing of Materials, in Teksid Aluminum's case, are the following:

- In the bottom-left portion of the window, the Product Tree represents the structure of the Equipment being browsed. In Teksid Aluminum's case this not very useful for the products, since they are all one-piece products, but it is very useful for production systems, having a complex structure, which seen in this window becomes clearer. Directly by clicking on the single system components/devices, the information on the related Equipment can be accessed and viewed in the Product Details window (bottom-centre of the figure)
- If, for the Equipment being browsed, there exist on or more files attached to it, these files can be viewed in the top-right portion of the screen (in the "Related Documents" window, Figure 26). The same files can also be opened just by simply clicking on them.

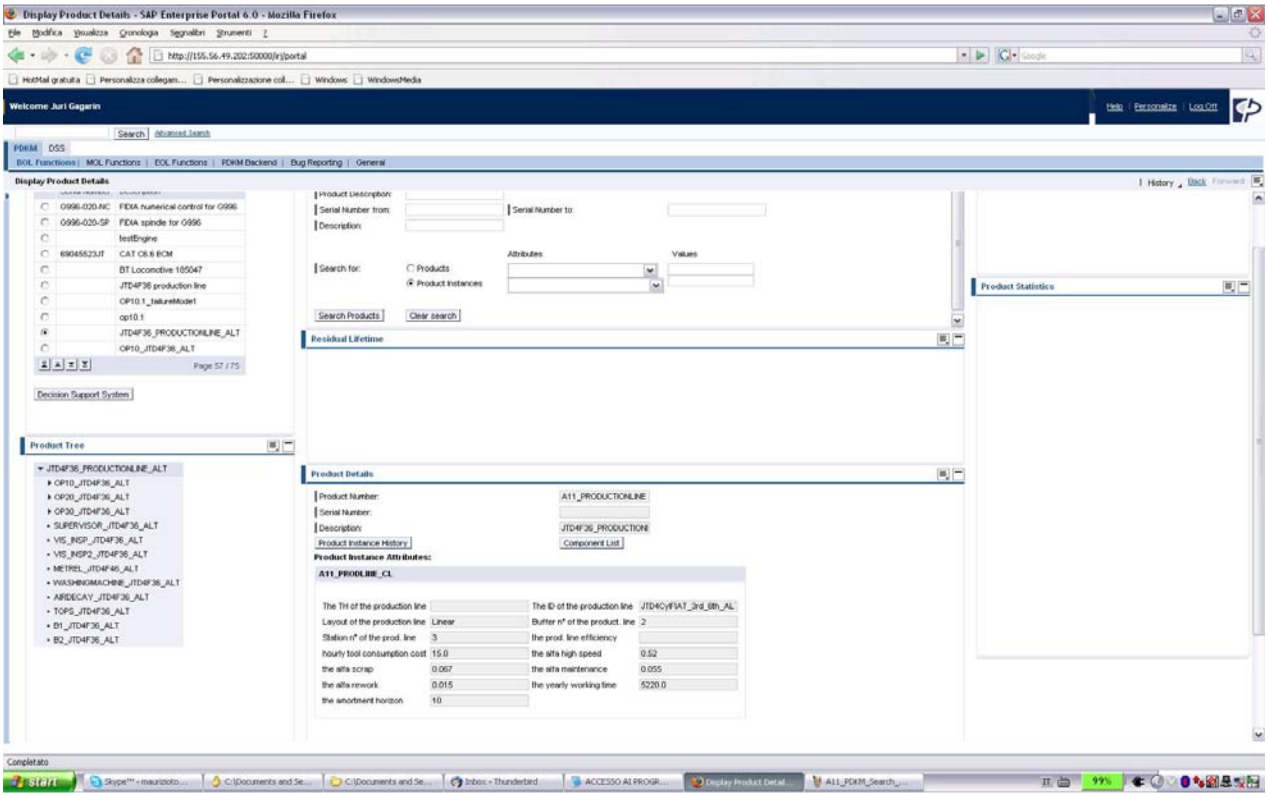

Figure 25: Browsing through A11 ”Equipments”

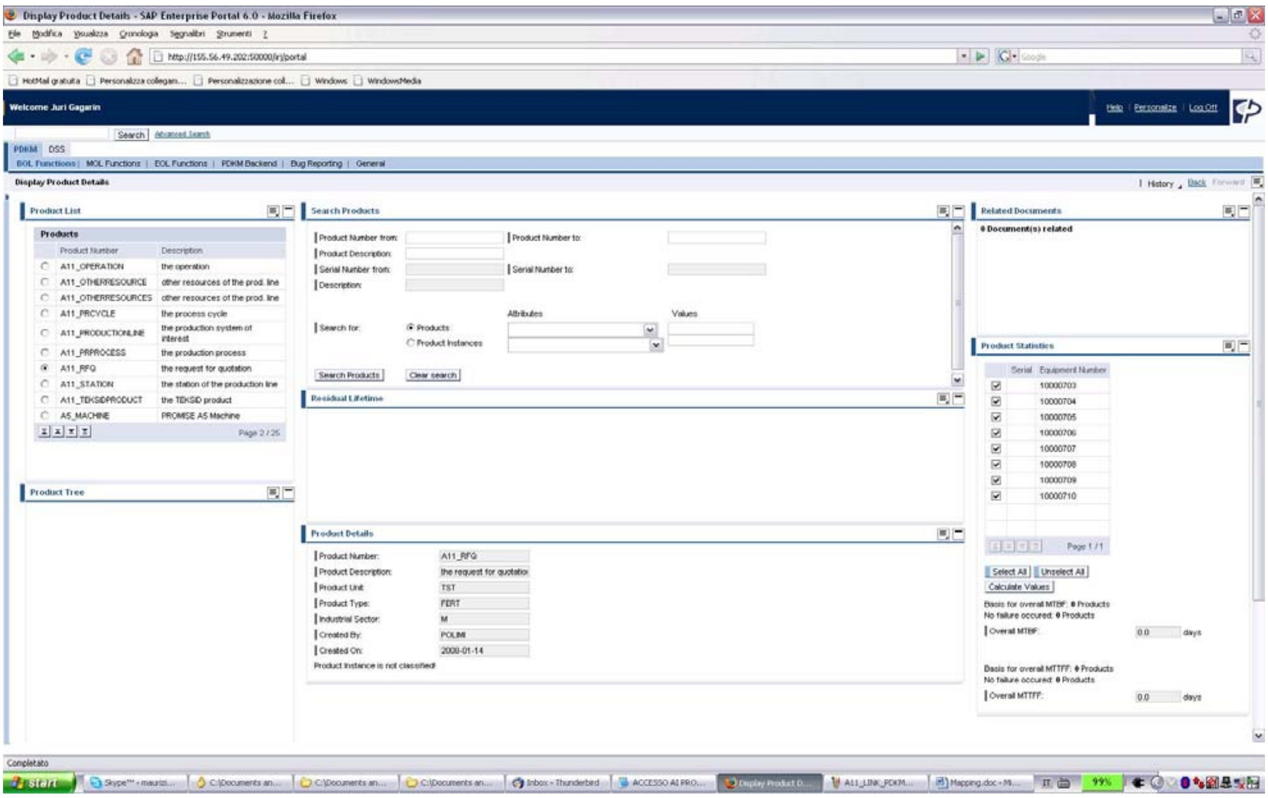

Figure 26: Browsing through RFQs (Requests For Quotations) in the Teksid Aluminum case

Finally, it is important to show that the decision-support functionalities (the same discussed in Scenes 1 through 3) of the A11 Adaptive Production software can also be accessed directly from the PDKM, e.g. after having entered the data to be assessed. On the top-left of Figure 27, in the

PDKM GUI, the user just has to click on the Decision Support System button. This opens the PROMISE DSS menu (Figure 28). There, the user can access the A11 POLIMI DSS, exactly as it was shown in the previous scenes.

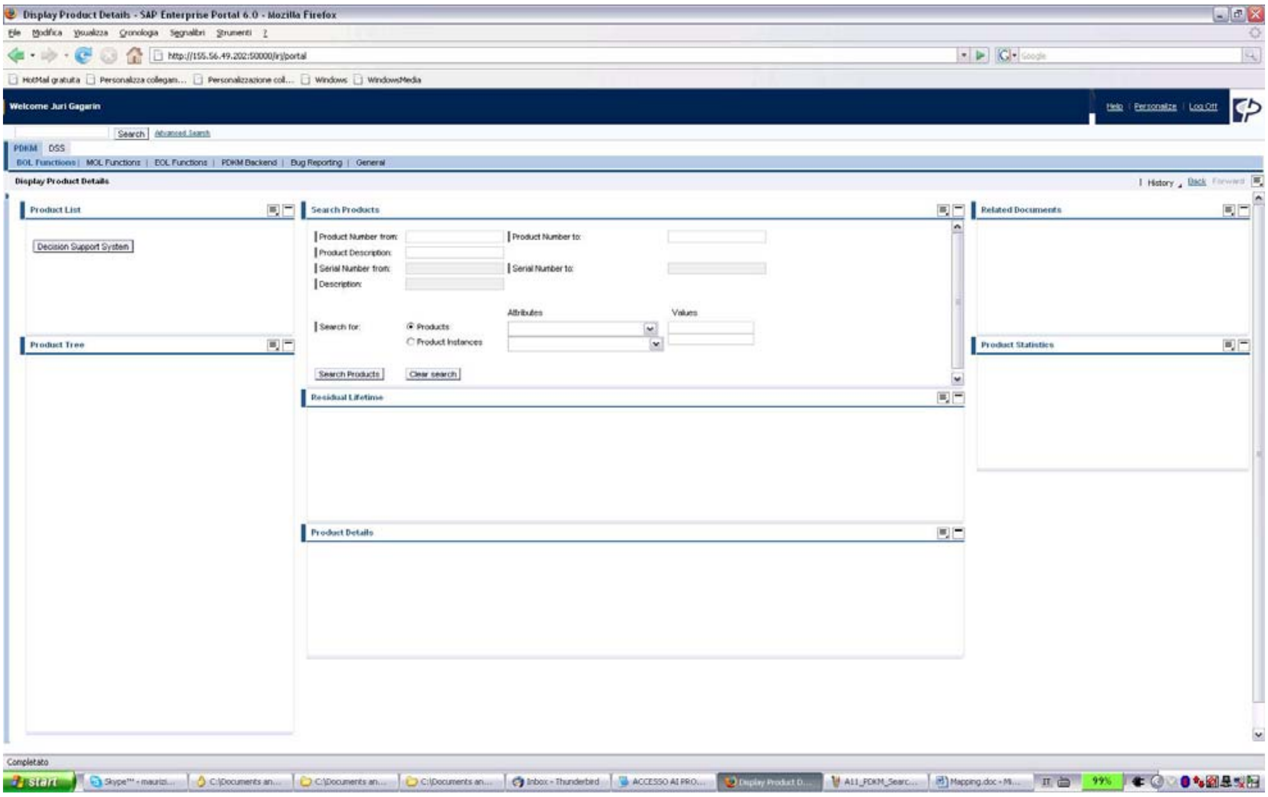

Figure 27: Accessing the A11 DSS directly from the A11 PDKM

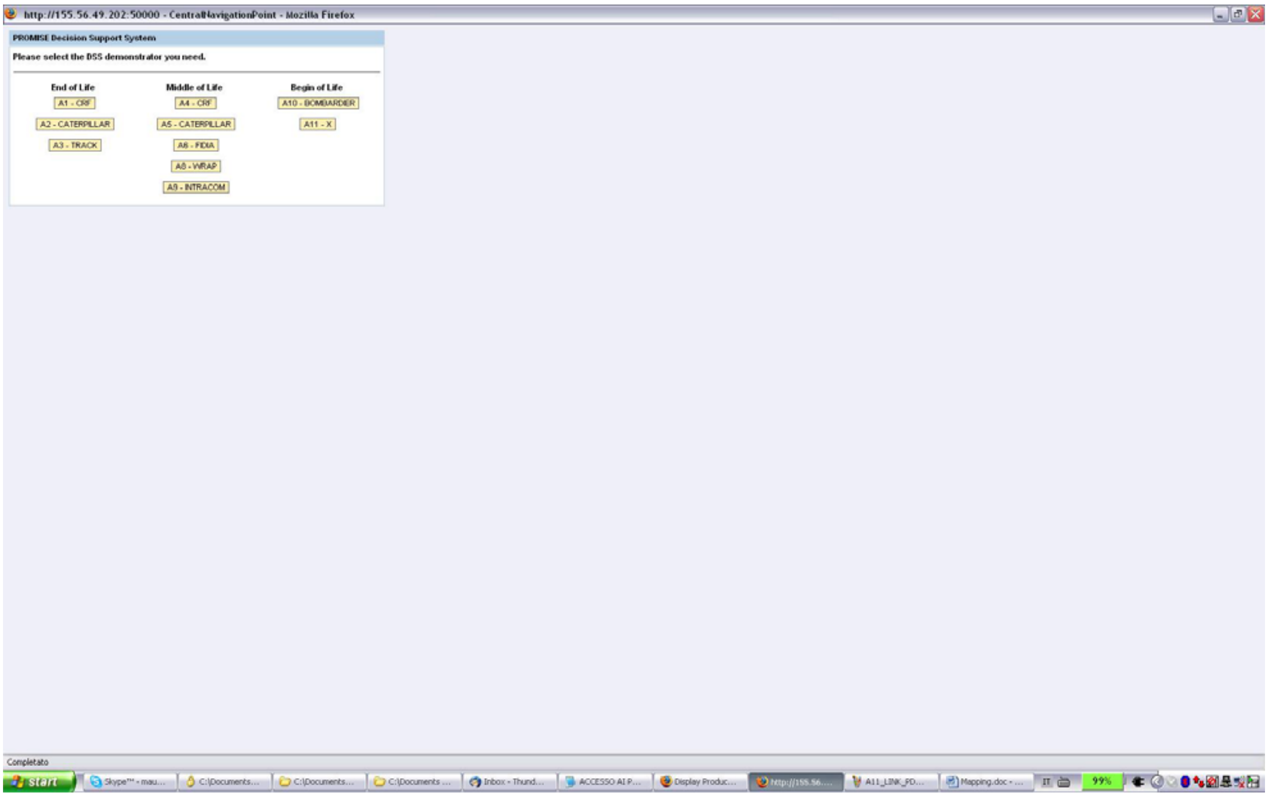

Figure 28: PROMISE DSS MENU as accessed from the PROMISE PDKM

5 Conclusion

In principle, all of the technical objectives of the A11 demonstrator have been met. There have been no technology barriers which have prevented the proposed implementation.

Concerning the success criterion defined by the Machining Platform engineers at Teksid Aluminum, i.e. that of reducing the time to prepare a Technical Offer (TO) of at least 50%, due to late finalization of the implementation of the demonstrator (because of algorithm-related implementation issues), it was not possible for Teksid Aluminum to check this success criterion directly at Carmagnola Plant. However, tests performed by the A11 research partner on cases such as those shown above, demonstrate that this time-reduction can reach up to 80%, given a really stable version of the system. This means that a typical field-data-based product modification can be assessed, and the related best solution found out, in one person-day instead of five person-days; the economical assessment of this improvement is fostered in the Business Effects and Sensitivity Analyses performed in the context of WP I3 and documented in the related deliverables.

The demonstration of the A11 scenes, successful in the Teksid Aluminum real case, also showed, because of their cross-application characteristics, a high business potential of the PROMISE Adaptive Production DSS Module in other future PROMISE implementations.

The lessons learned while developing the Teksid Aluminum implementation, have finally provided A11 partners with useful insights on how to exploit the same structure of algorithms and the PROMISE PDKM/DSS architectures in other real cases, as well as on how new application-specific algorithms providing the same functionalities can be developed/implemented relying on the same structure.