SIXTH FRAMEWORK PROGRAMME

HORIZONTAL RESEARCH ACTIVITIES INVOLVING SMES

CO-OPERATIVE RESEARCH

EMPOSME

Enterprise Modelling and Performance Optimisation For SMEs

Contract No: 018071

Final Activity Report (Publishable)

including the

Final Plan for using and Disseminating the Knowledge

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Executive Summary Publishable

Project Objectives

The primary objective of this consortium was to develop and implement an Enterprise Modelling and Performance Optimisation (EMPOSME) tool. EMPOSME integrates Enterprise Modelling and Enterprise Optimisation so that the decision maker can rapidly identify the risk/reward position of any choice he has to make vis-à-vis a suite of defined key performance indicators.

Our focus is on firms that operate on an Engineer to Order (ETO) and Make to Order (MTO) basis. The complexity of the product life cycle in these industries has been continuously increasing. An integrated Enterprise Modelling and Performance Optimisation tool, such as EMPOSME, is an enabling technology for both increasing the speed and the flexibility of these manufacturing enterprises, and thus their competitiveness. EMPOSME enables practitioners to efficiently create an Enterprise Model and automatically transform this model into an Enterprise Optimiser that generates near optimal solutions to their required set of performance metrics.

While there are a range of commercial ICT technologies currently available that make a similar claim, in practice these solutions tend to model only small portions of the entire product life cycle. Manufacturing firms have an immediate requirement for Enterprise Modelling and Performance Optimisation that will enable them to deploy their limited resources for maximum economic yield for the entire life cycle of the products it places on the market.

EMPOSME is based upon existing ERP legacy systems and/or an Open Source ERP (ERP5) application. The project results include:

- **An Open Source Enterprise Modeller** that enables the practitioner to succinctly describe the Enterprise.
- **An Automatic Enterprise Optimiser Software Generator (which will be available as a Web Service late 2008) for model execution** generates near Optimal solutions to the user specified set of performance metrics (Closed Source due to utilising existing commercial APIs).
- **An Enterprise Performance Manager** that enables the practitioner to Specify, Evaluate, Diagnose and Improve Performance outcomes (Closed Source due to utilising existing commercial APIs).

These project end-results were achieved through the science and technical objectives which has enabled the experienced practitioner within an SME to accomplish the following:

- Rapidly model and accurately represent all of the Entities (e.g. sales orders) and Resources (e.g. People and Machines) within the typical firm via a visually appealing user Interface.
- Enable the practitioner to define his multi-criteria Enterprise Objective function or goal.
- Enable the manager to rapidly diagnose and resolve the myriad of resource conflicts that emerge frequently within an enterprise.

- Enable the manager to evaluate the proposed solution and deploy it to people that complete the value generation activities within the firm.
- To develop and implement an integrated software solution to achieve an 'holistic optimised resource allocation solution' needed to process all sales orders in MTO and ETO industries for a near-optimum solution from initial quotation to return of the product at the end of its useful life.

Overview of the End Results

EMPOSME integrates Enterprise Modelling and Enterprise Optimisation so that the decision maker can rapidly identify the risk/reward position of any choice he has to make vis-à-vis a suite of defined key performance indicators. The EMPOSME suite of tools, as validated through deployment at the SME end-user sites, is used as follows (and described in Figure 1,2):

(1) The end user interacts with the **Enterprise Modeller** to describe (or model's) the entities in the organisation at enterprise level relevant to the main Key Performance Indicator. The data for the Supply-Demand Position is extracted real-time from the ERP system and / or legacy databases such as spreadsheets.

(2) The **Optimisation and Planning Module** then plans multiple resources vis-à-vis a suite of Key Performance Indicators. The plan is integrated, e.g. unlike standard planning systems the material optimisation does not assume infinite capacity and vice versa. The plans also allow for user interaction so that the practitioner can use his/her empirical experience to adjust the plan using visual interfaces to display the consequence of his/her decision on the relevant performance indicator.

(3) The **Performance Manager** shows the impact of the planning decisions taken today on the Key Performance Indicator (Predictive Performance Planning). For example a series of visually interactive screens show the predictive performance of the enterprise based on the plan produced. The decision maker can thus rapidly identify the risk/reward position of any choice he has to make vis-à-vis a suite of defined key performance indicators.

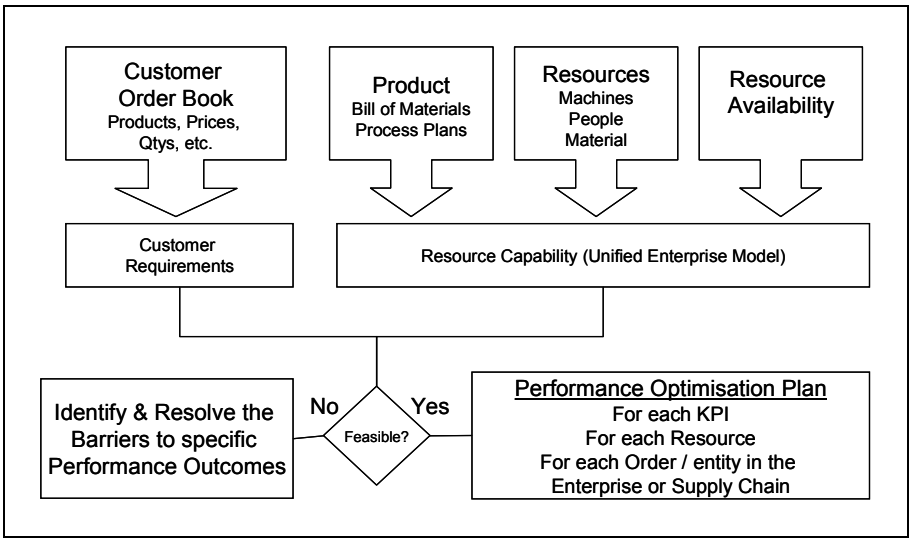


Figure 1: Overview Description of the Enterprise Model for the OTIF KPI

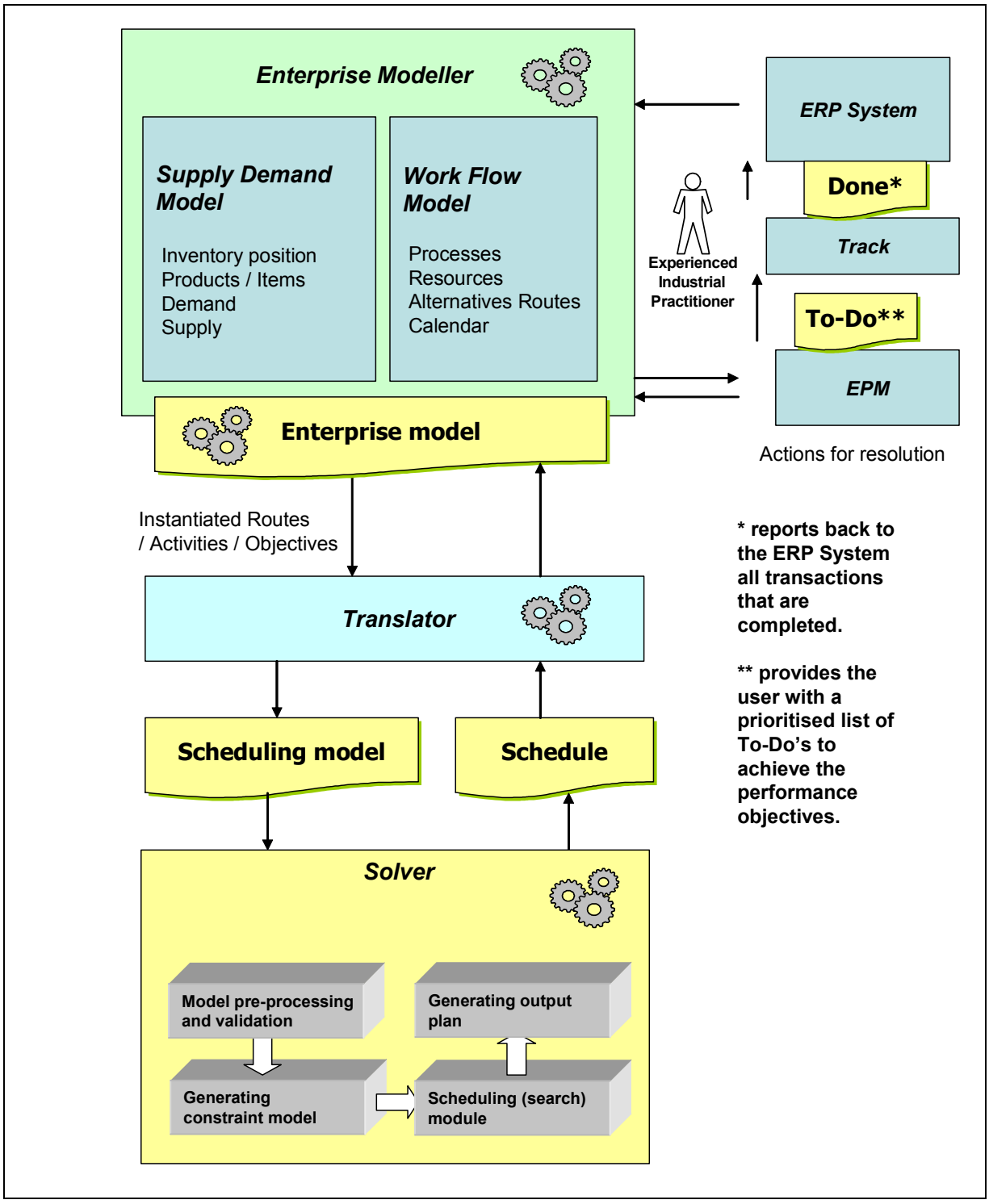


Figure 2 EMPOSME System Architecture as implemented

Contractors involved

The EMPOSME Consortium assembled in response to the consortium conclusion that SME enterprises are not exploiting the potential of enterprise modelling and optimisation technologies to maximise their performance. The consortium assembled the critical research capabilities from across the EU to address these challenging domains:

Co-Ordinator:	Dr. Con Sheahan, University of Limerick, Ireland
Enterprise Performance:	Prof. Hans Henrik Hvolby, Dr. Kenn Steiger Jensen Aalborg Universitet, Denmark
Enterprise Modelling:	Prof Ulrich Frank Jonas Sprenger Universitaet Duisburg-Essen, Germany.
Optimisation:	Prof Eugene Freuder and Dr. James Little Cork Constraint Computational Centre, UCC, Ireland, Dr. Roman Bartak, Univerzita Karlova V Praze, Czech Republic .

These skills are combined with the SME software firms ManOPT Systems Ltd. and Open Source ERP5 Developer Nexedi.

A number of innovative SMEs are included to ensure that the core focus of the project of bringing Enterprise Modelling and Optimisation technologies to all firms is validated within small firms.

The entire project is being coordinated by the University of Limerick whose department of computer science is recognised as a key contributor in the development of Open Source and Libre software. The entire consortium includes:

University of Limerick	Ireland	Co-Ordinator / RTD
Aalborg University	Denmark	RTD
Univerzita Karlova v Praze	Czech Republic	RTD
Cork Constraint Computer Centre (4C)	Ireland	RTD
Universsistat Duisburg-Essen	Germany	RTD
Nexedi SARL	France	SME
FIRA International	United Kingdom	RTD
ManOPT Systems Ltd.	Ireland	SME
Burnside Eurocyl Ltd.	Ireland	SME
Tippo International Ltd	Ireland	SME
Dolle AS.	Denmark	SME
Morsoe AS.	Denmark	SME
Millhouse Design Ltd.	United Kingdom	SME

Work Completed

The work in the first period focused on getting to prototype stage of the tool with one SME end-user partner.

1. capturing the main **requirements** from SMEs, (WP2)
2. developing **reference models** from their process models, and proposing a **new Meta model** for a production modelling language (WP2 / WP3),
3. proposing a formalism to model the **Scheduling problems** (WP3),
4. starting implementation of the **solver prototype** (WP4),
5. developing a portfolio of **performance metrics** (WP5),
6. **deployment of the initial prototype** at one end-user site (WP6), and
7. disseminating the knowledge through publications.

The second period focused on the generalisation of the EMPOSME tool and validation of the concepts developed during P1. This included specific work such as:

1. **Extending the initial market survey** to a wider representative of the industry, especially the development of a generic set of performance metrics to be used for optimisation (WP5).
2. **Extending the metamodelling concepts** provided by UDE in WP3 to include the concepts of enterprise modelling for optimisation and performance modelling.
3. The automatically generated optimisers have been tested in production situations and it was found that by focusing on the core model elements there is significant commonality between the model structures from the individual end user firms. This presented the opportunity to develop a very powerful **generic optimisation solver** that performed well in all of the problem test sets.
4. **Integration** the enterprise model with the optimisation model for the general case.
5. Development of new **generic scheduling model** that describes the core of the production scheduling problem was developed. The development of a new generic model for scheduling problems with process and resource alternatives is the first time such a model has been formalised for scheduling problems.
6. Development of **the solver** to include several new filtering algorithms for constraints integrating reasoning on numerical variables (temporal relations) and logical variables (dependency constraints). These algorithms have been evolved through a series of iterations with a particular focus on the time of execution.
7. Additional functionality was added to the solver to **validate the models** built by the practitioners. In particular, algorithms were developed for discovering equivalence classes of activities, that is, activities that must be present (valid) together in the schedule. This is a part of more general pre-processing that discovers logical relations between activities. This pre-processor can also deduce some formal bugs in the model. This **enables the manufacturing practitioner to build enterprise models**, previously the domain of modelling and optimisation experts.
8. Development of a generic set of **Performance Measures** for optimisation that emerged as key priorities for SMEs in general.

9. Development of the **Performance Manager** to
    - First, identify and draw attention to possible future problems. Early identification of problems facilitates corrective action within the window of opportunity to do so.
    - Second, to make an optimal plan based on the current status in the production (orders, materials on hand, available resources, transport agreements etc).
    - Third, to show the impact of the planning decisions taken today on the Key Performance Indicator (Predictive Performance Planning).
10. **Deployment** and Validation of the EMPOSME tool and concepts at the SME end-users.
11. **Development** of **ERP5** to make the tool accessible to SMEs and configurable with the EMPOSME tool including:
    - the "Business Template" technology which provides a base abstraction of corporate information system, and
    - the "ERP5 Express Wizard" technology which automates the configuration of business templates to meet SMEs requirements.

The following will now describe a summary of each of the above work elements as completed.

Requirements Analysis

During P1 the main **requirements analysis** has been done in cooperation with Universitaet Duisburg-Essen, Univerzita Karlova v Praze, ManOPT Systems Ltd., and University of Limerick. It focused initially on the modelling requirements of two SMEs in the project, namely Burnside Eurocyl Ltd. and Tippo International Ltd. In parallel, Aalborg Uniiversitet worked in gathering requirements at the end-user firm Dolle, and assisting Dolle in preparation for implementation. Additional input has been taken from Cork Constraint Computer Centre and FIRA International Ltd., the latter who contributed requirements from a market study. The result of this work is a document describing the production and management structures of the two SMEs. This document served as the primary source of information for problem modeling.

FIRA has played a crucial role in establishing the needs of a major manufacturing sector – that being furniture. A questionnaire was constructed, refined and distributed to a selection of over 50 SMEs in the UK, Cyprus and Spain so that a good European perspective was obtained. This work has been useful for establishing the parameters that differing manufacturing sectors share and where major user needs deviations might occur. The response to the questionnaire was however disappointing (11 replies from 50) and was limited to the furniture industry.

The initial survey did confirm however that the selected key performance indicator for the initial prototype '**On-Time-In-Full'** was indeed the key priority for SMEs. In order to generalise the EMPOSME tool, further work was required, in P2, particularly in the area of performance management.

The empirical experience from the SMEs in the consortium, and wider a field, was that performance management is not used in a structured way, for either decision making or optimisation, by the vast majority of SME companies. Historically, PM (Performance Measurement) systems have been developed as a means of monitoring and maintaining organisational control in multiple disciplines, but the majority of SMEs are still relying on traditional financial PMs. A number of reasons emerged as to why performance management was not used for running, controlling or optimising the SME enterprises. The *primary reason was the lack of a practical, easy-to-use, operational, generic, performance measurement system suitable for SMEs and capable of tracking operational issues that were of common concern.*

WP5 then set out to determine a set of operational GPMs (Generic Performance Measures) and identify the inter-relationships that existed between them with respect to decision choices. The research concepts are reported in EMPOSME Deliverable Report D5 – Design and Development of a generic operational enterprise performance measurement system. The tasks, performed by UL, Aalborg and ManOPT, included:

- an extensive review of literature on the topic of Performance Measures; 568 Performance Measures were identified through literature review.

- 50 structured interviews using a survey instrument based on the results from the literature review. This was carried out in 50 companies internationally, with owner-managers, company heads and/or company founders lasting 2-3 hours per interview. The sample used in this research included companies as diverse as electronic suppliers, to door

manufacturers to regional co-ops / non-hierarchical networks. Surveys were completed in Ireland, Denmark, Italy, China, England, Germany, Switzerland, Holland, Australia, Sweden and the USA.

- A workshop, (November 2007) was used to confirm the top measures; participants included SME owner-managers, service suppliers, semi-state representatives as well as academics and industry advisors. The workshop was featured in the 'Technology Ireland' publication, See: EMPOSME D7 Annex 1 - Performance Measure Workshop Magazine article.

The main set of Performance Measures that emerged as key priorities for SMEs included:

- On time in full (OTIF)
- Right first time
- Profit (per product)
- Sales generated (order book)
- Sales per month (past)
- Cash flow.

The challenge then became in P2 how to generalise the model of the enterprise to ensure that each of the above KPIs could be modelled for performance optimisation. (The following screenshots show the results of how these KPI's were optimised in production scenarios in Work Package 6 to enable the decision maker rapidly identify the risk/reward position of any choice he has to make vis-à-vis a suite of defined key performance indicators.

Figure 3: Enterprise Performance Reporting and Analysis – Plan Vs Actual

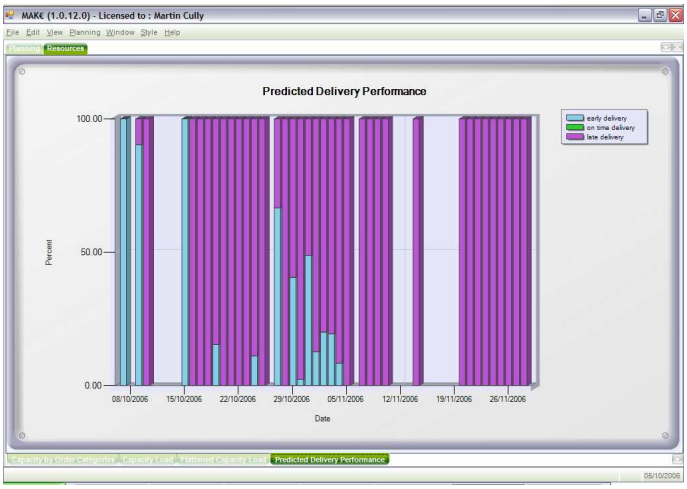


Figure 4: Predictive Performance for the optimised Supply-Demand Plan for OTIF

Enterprise Modelling for Performance Optimisation

In P1, Process models of two-end users were used to develop first drafts for the **reference models generation**. The reference models, developed by UDE, provide an adequate opportunity to reduce the model build effort which to-date has been a barrier to deployment of optimisation technologies, particularly in SMEs. This resulted in a **Meta model** for a production modeling language. This Meta model could be used together with a list of graphical symbols to implement a modeling tool. The Meta model encompasses among other concepts resources and processes. Based on these concepts an interchange format for the solver could be found in collaboration with 4C and the University Karlova. This interchange format is based on XML. A XML-DTD ensures the structure of the input for the optimisation models. Beyond this a procedure is proposed to build product families and reference models to reduce the model build effort. On a base of reference model a generator could derive the concrete models by modifying pre defined values.

In P2 UDE delivered an ***open source modelling tool*** that allows designing enterprise models in the domain of manufacturing. Eclipse (www.eclipse.org) has been used as frontend for the development of the enterprise modelling tool (EM tool) that provides manufacturing-specific concepts and terminology. It can be used to design and maintain enterprise models. This aspect and in particular the fully available Java source code allow the distribution of the tool and the source code to an open source community. This fully meets the requirement of providing of an open source modelling tool. The openmodels.org website (www.openmodels.org) hosts the Open Model Initiative, a project to collaboratively develop enterprise reference models for everyone to copy, use, modify, and (re-) distribute in an open and public process.

In addition to the metamodelling concepts provided by UDE in WP3, significant work on the concepts of enterprise modelling for optimisation and performance modelling was required in WP6 to develop a prototype that met the entire set of objectives. **The concept of dynamic optimisation (online scheduling) is itself new and required an enterprise modeller that could represent the dynamic nature of the enterprise.** The enterprise modelling tool deployed in the prototypes at the SME partners, furthers the meta-modelling concepts from UDE with enterprise modelling concepts from UL, instantiated in code by the software development partner ManOPT. The development was iterative (20 release builds in total) as requirements emerged from end-users (Burnside, Tippo, Millhouse, Morsoe, Dolle), optimisation partners (WP4 4C, Karlova) and the performance management group (WP5 UL and Aalborg).

The primary modelling requirement for an optimisation solver is the detailed description of the system or problems for solving and related data. However, due to different characteristics and features of various discrete optimisation systems, there is no one generic tool that was capable of fulfilling this requirement. (EMPOSME fills this gap). In addition, the commercially available tools require some specific knowledge (by optimisation and/or modelling experts) in order for users to work on it. The modelling tool that has been developed within EMPOSME had as the objective of keeping it as simple as possible to facilitate practitioner use. **The main focus was to develop a modelling tool for manufacturing applications in order to assist SME's in improving performance**. The modelling tool developed proved so intuitive that, by adapting extreme programming concepts to the training of the end-users, within 3 days of collaborative modelling with the software developer, the SME practitioner (who had no prior modelling or optimisation experience) were confident to continue to build their models unaided.

The modelling tool includes a set of functionalities that enable users describing all entities involved in the system, as well as the mathematical relationships between these entities. The basic functionalities of the modeller include:

- Editing all resources, states and activities that could exist in the system, including their parameters.
- Editing the relationships between states, activities and resources; transactions between states, and alternates for execution.
- Editing the calendar for single resources, combinations of resources.
- Editing state and activity workflows.

It is important to keep in mind the dynamic aspect of the orders arrival in the context of the SME. We have therefore continued to evolve the suite of online optimisation models to determine ways optimisation can be used in a changing environment with orders arriving all the time and importantly, whether they can be scheduled or not.

The initial development work was done using the Netron diagramming library (http://www.orbifold.net/netron/info.php). Netron is a generic diagramming, graph-drawing and graph-layout kit for the Microsoft .Net framework written in C#. The free version is **licensed under GPL.** The development of Netron has been discontinued and there is no further support. Netron redirected all the original sites to Northwoods Software. The development now uses The GoDiagram library, from Northwoods (http://www.nwoods.com/go/dotnetconcepts.htm). GoDiagram is a set of controls and classes built on the .NET platform.

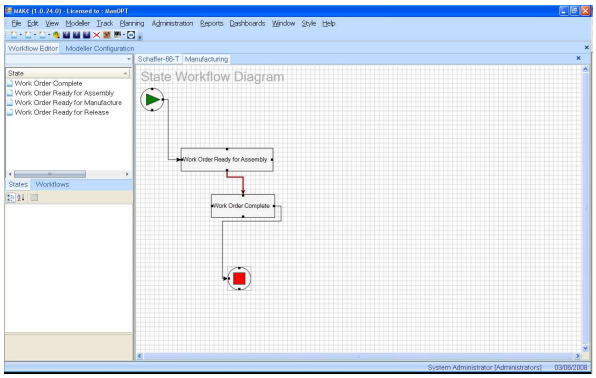


Figure 5.1 Workflow State Definition

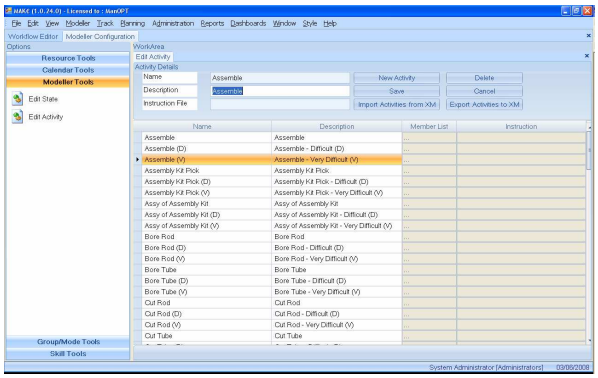


Figure 5.2 Definition of Activities

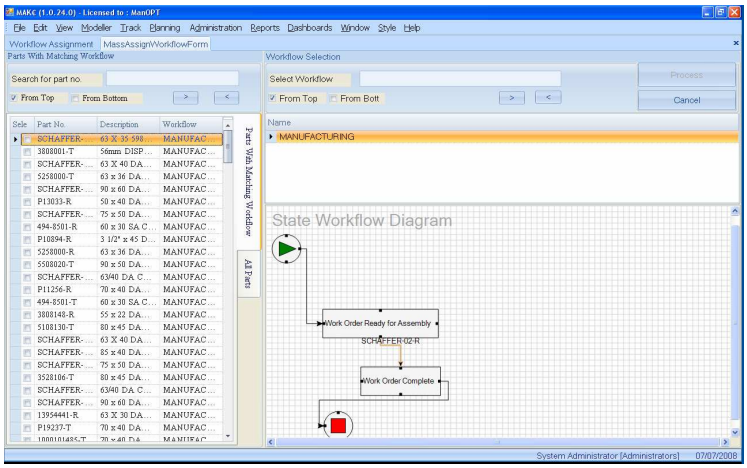


Figure 5.3 Workflow Assignment to specific Purchase and Work orders

Optimisation for Enterprise Performance

An important lesson learned during the development of the EMPOSME toolkit is the importance of having a high quality representation or model of the reality of the firm. In practice it took tremendous effort by all partners to advance the state of the art in enterprise modelling.

An original goal of the EMPOSME project was to use the Enterprise Model to automatically generate optimisers for the each of the end user firms. The project has exceeded this goal. The automatically generated optimisers have been tested in production situations and it was found that by focusing on the core model elements there is significant commonality between the model structures from the individual end user firms. **This presented the opportunity to develop a very powerful generic optimisation solver that performed well in all of the problem test sets.**

4C focused on developing and implementing a specification for how the enterprise model communicates through an XML model to the optimisation model. This is the key piece joining the two paradigms together and enabling process designers / production engineers / managers to automatically obtain good scheduling results. This interface works both ways in passing the required information in terms the enterprise modeller understands and in a way which is complete for the scheduling model. In others words, a first steps consists of (a) generating the XML from the enterprise and (b) parsing (analyse and interpret) it in order to obtain relevant information for the scheduling point of view. Since the enterprise model does not define itself in terms of activities and resources (scheduling concepts), these need to be determined and extracted. Once the scheduling itself is done, the second steps take place. These consist of: (c) retrieving the results and converting them into an XML file and (d) this XML file is converted into an enterprise model which feeds back to the user.

A new **scheduling model** that describes the core of the production scheduling problem has been developed. For this model, both its semantics and Prolog-like syntax have been formally described (See WP4). The development of a new generic model for scheduling problems with process and resource alternatives is the first time such a model has been formalised for scheduling problems.

Univerzita Karlova implemented **the solver** based on constraint satisfaction technology available in SICStus Prolog. The solver takes the enterprise model as its input, validates the model, uses newly developed constraints to solve the problem, and produces schedules satisfying production requirements. It contains **several new filtering algorithms** for constraints integrating reasoning on numerical variables (temporal relations) and logical variables (dependency constraints). These algorithms have been evolved through a series of iterations with a particular focus on the time of execution.

At the end of the P2 period the optimisation solver is an executable module of code that is compiled utilising the SICStus API development library. This structure was adopted so as to ensure that all of the CPU resources are utilised for optimisation once the EMPOSME optimiser is executing. This structure also exploits the recent developments in computer architecture where multiple CPU cores are available which allows the optimiser to run in parallel with the EMPOSME Enterprise Modeller.

As previously stated the goal of EMPOSME to enable the manufacturing practitioner to build enterprise models, previously the domain of modelling and optimisation experts has been achieved. Additional functionality was added to the solver, in the newly designed pre-

processing module, to validate the models built by the practitioners. In particular, algorithms were developed for discovering equivalence classes of activities, that is, activities that must be present (valid) together in the schedule. This is a part of more general pre-processing that discovers logical relations between activities. This pre-processor can also deduce some formal bugs in the model. This pre-processing and validation of the Enterprise Models as they were transferred from the Enterprise Modeller to the Optimiser Solver is essential to ensure that the models that the practitioners developed are logically valid. This is especially important when one is utilising the CSP formulation of the problem since if one presents a logically invalid problem to the solver then there is a risk that the practitioner will not get a solution to the decision scenario at hand.

The current scheduling (search) strategy has performed very satisfactory for real-life problems tested from the end user firms. The scheduling strategy takes in to account three main considerations of the SME end-user.

- The *objectives need to specified in the model*, rather than using a "hard-coded" objective that is typical of optimisation software. This facilitates optimisation against a suite of KPIs either individually or collectively depending on the commercial situation the SME is in at one time. For example while on-time-in-full may be a long term goal, cost may be the deciding factor in another contract.
- The *experience of end-users* with running the factory from generating schedules manually should not be under-estimated. Based on the visualisation of the performance in the Performance Manager Module, the user can interact with the optimisation plans produced to adjust the plans based on his/her experience. It is important that the end-user can 'trust' and 'own' the solution.
- The *available time to solve the problem*. The optimised plan must be produced within a time-frame that enables the practitioner to take action within a timeframe that is constantly reducing due to time pressures within the typical SME. The solver produces a result within ten minutes typically. For example the solver function runs in less than 10 minutes on a production database of 20,000 enterprise entities including:
    - Supply-Demand Entities (Sales Orders, Purchase Orders, Works Orders
    - Resources , and
    - Inter-Entity relationships (BOMs, Workflows).

  The most common benchmark in the literature in the MT10 (Muth Thompson) benchmark which contains 100 operations.

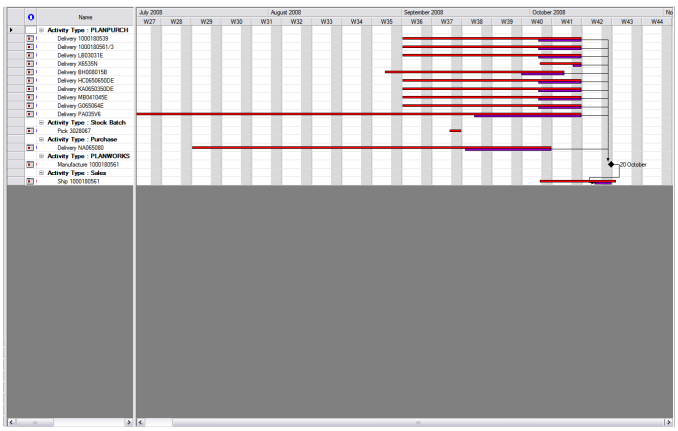


Figure 6: Solution to the production scheduling problem in use at SME end-user.

The Performance Manager

Aalborg's main role in the project was in the area of the conceptual design of the **performance manager**, which was then developed and implemented by the software developer partner ManOPT. Their focus was ensuring that the modeler and optimiser contribute benefits to the performance outcomes of the SME end-users. They have worked primarily on the integration of the constraints and functionality for the optimiser with Key Performance Indicators.

The value of the optimiser to performance management is to

- First, identify and draw attention to possible future problems. Early identification of problems facilitates corrective action within the window of opportunity to do so.
- Second, to make an optimal plan based on the current status in the production (orders, materials on hand, available resources, transport agreements etc).
- Third, to show the impact of the planning decisions taken today on the Key Performance Indicator (Predictive Performance Planning).

In managing the operational performance of an enterprise it was found during the implementation of the EMPOSME toolkit that there are four main phases of activity by the SME practitioners. This is a typical **Plan-Do-Check-Act** cycle. However what is unique to EMPOSME is that the user can see the predicted outcome of the action before the execution and can therefore adjust the plan or action to achieve a better outcome.

Phase 1: Working upon and diagnosing the issues with the supply of prerequisites **external resource** (mainly supplies) raw materials, components, tooling and sub contract services. In this phase, the user sees the order books, for example a Sales Order and from here we can see how the supply-demand matching has 'pegged' the orders. The tree diagram on the right allows the user to diagnose problems in supply-demand matching. This diagram is interactive and allows the users to drill up and down through the 'pegging' hierarchy. On the bottom we have the order profile for the part on the order. This shows all incoming and outgoing orders for the part. ***This is one example of how the tool enable the manager to rapidly diagnose and resolve the myriad of resource conflicts that emerge frequently within an enterprise.*** Furthermore it facilitates the scheduling strategy to take into account the experience of the end-user, as previously discussed, building 'trust' and 'ownership' of the solution.

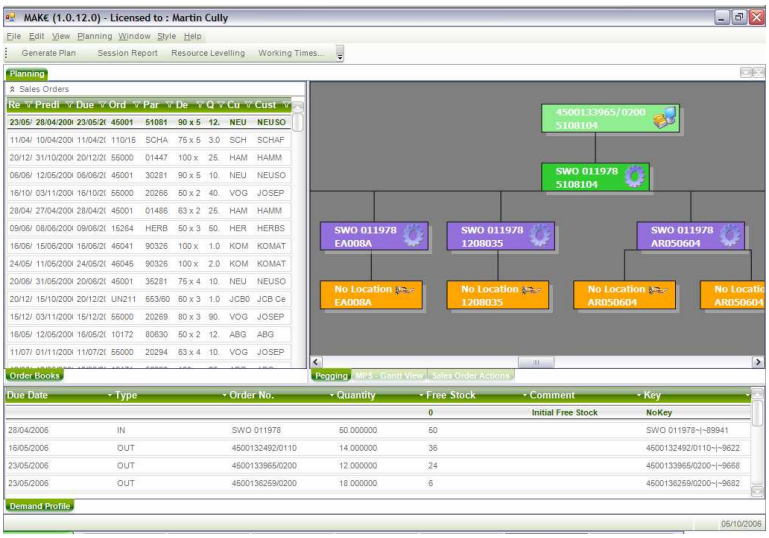


Figure 7.1 Supply Demand Plan (material) for OTIF KPI

Furthermore, it is well known that at any one time a manufacturing practitioner has a very large variety of tasks on his to-do list. The most critical contribution for the EMPOSME toolkit is to provide prioritised support to the SME practitioner for diagnosing the most critical problems that affect his selected KPI. ***This is another example of how the tool enables the manager to rapidly diagnose and resolve the myriad of resource conflicts that emerge frequently within an enterprise***. It also facilitates the end-user to take action within a useful time-frame.

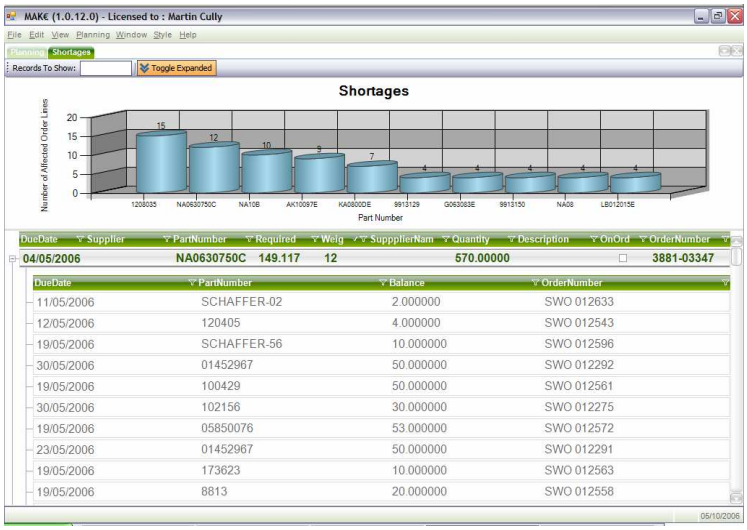


Figure 7.2 Priority External Material Supply Issues that impact negatively upon OTIF KPI

Phase 2: Working upon and diagnosing the issues with the supply of prerequisites **internal resources** (mainly capacity) time resources for machine tools, work centres and people

Here we can see the capacity load against a resource over time. This chart also breaks the demand up depending on the source whether it is a sales order or a forecast order. This can assist the user in the decision making process, as demand from some a forecast order type may not be as important as an actual sales order. ***This is another example of how the tool enable the manager to rapidly diagnose and resolve the myriad of resource conflicts that emerge frequently within an enterprise***.

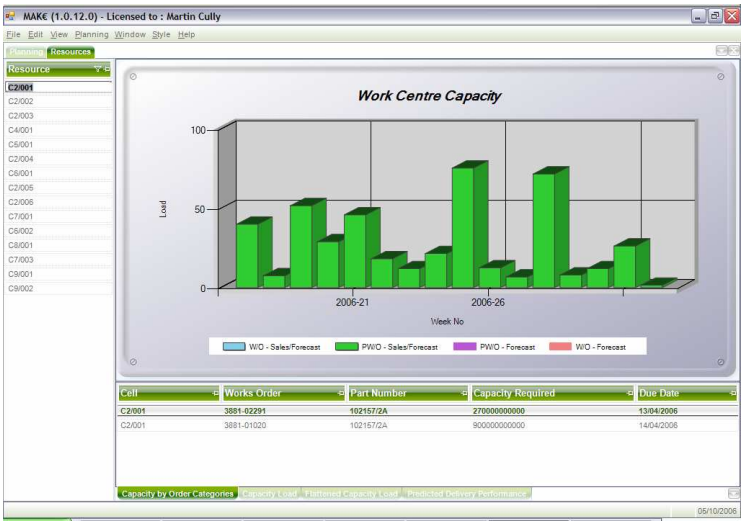


Figure 7.3 Resource Plan (Capacity) for OTIF KPI

The Performance Manager shows the impact of the planning decisions taken today in Phase 2 on the Key Performance Indicator (Predictive Performance Planning). For example the screenshots 7.4 shows the predictive performance of the enterprise based on the plan produced. The User can interact with either the planning screens to effect the result.

This demonstrates how the tool enables the manager to evaluate the proposed solution and deploy it to people that complete the value generation activities within the firm. Furthermore it demonstrates how **the decision maker can rapidly identify the risk/reward position of the choice he has to make vis-à-vis a suite of defined key performance indicators.**

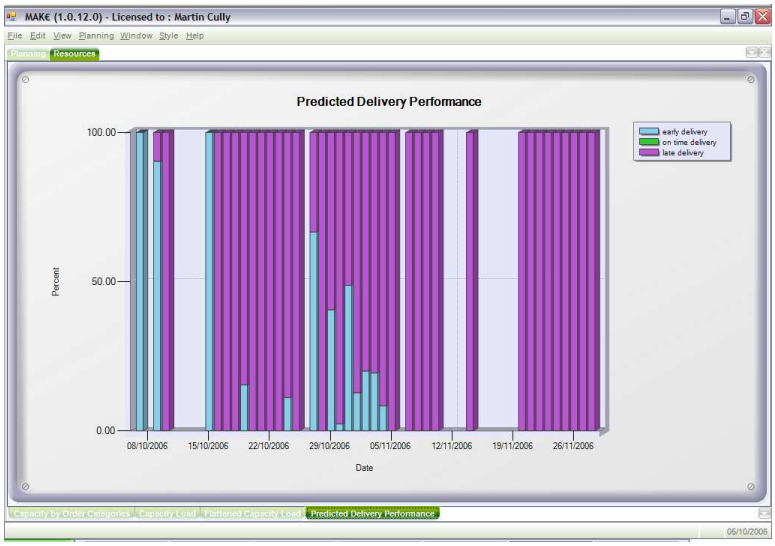


Figure 7.4: Predictive Performance for the optimised Supply-Demand Plan.

Phase 3: The operational execution of the prerequisite work, purchase subcontractor order workflows that are the prerequisite for each sales order that is fulfilled from the firm.

Once the plan is accepted orders can be released to manufacturing (Figure 7.5) and 'to-do' lists (Figure 7.6) are automatically produced for either each user, machine or material e.g. what sequence of tasks the operator has to do; what sequence of jobs to go on the machine; what purchase orders to place, expedite etc. As each transaction is completed the status of the order is tracked.

In order for the decision maker to make valid decisions he has to have a full understanding of the **current state** of the enterprise. The automatic monitoring or tracking system is needed to capture events and information existing in the enterprise system as each of the sales order and their component orders progress through their lifecycle. **The Track System** (which was not identified in the original workplan) has proved to be a key component of the EMPOSME toolkit in that it captures all of the events that characterise the critical performance issues of the enterprise. The primary reason, that emerged from the interviews with SMEs, as to why SMEs did not engage in performance management, was the lack of a practical, easy-to-use, operational, generic, performance measurement system suitable for SMEs and capable of *tracking operational issues* that were of common concern. EMPOSME leverages from the enterprise modeller functionality that provides a real-time representation of the enterprise to the optimiser to do likewise for the practitioner and bridges this significant deployment gap for SMEs.

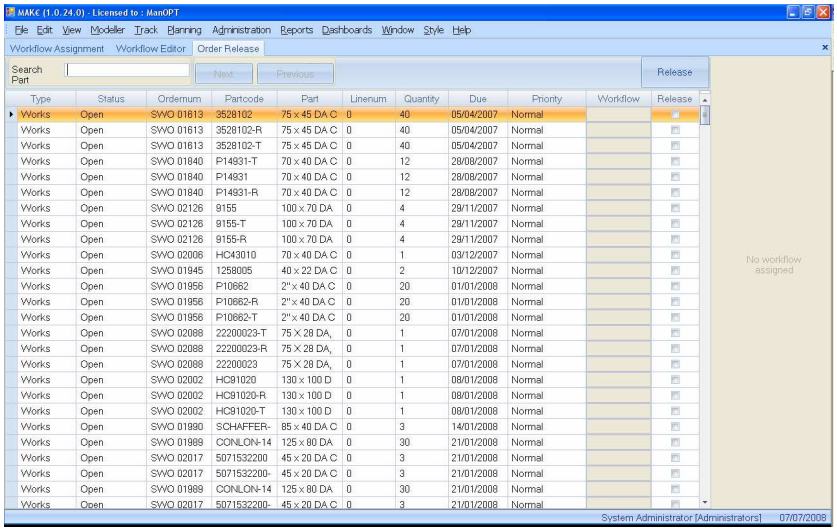


Figure 7.5: Work Order Release (Execution)

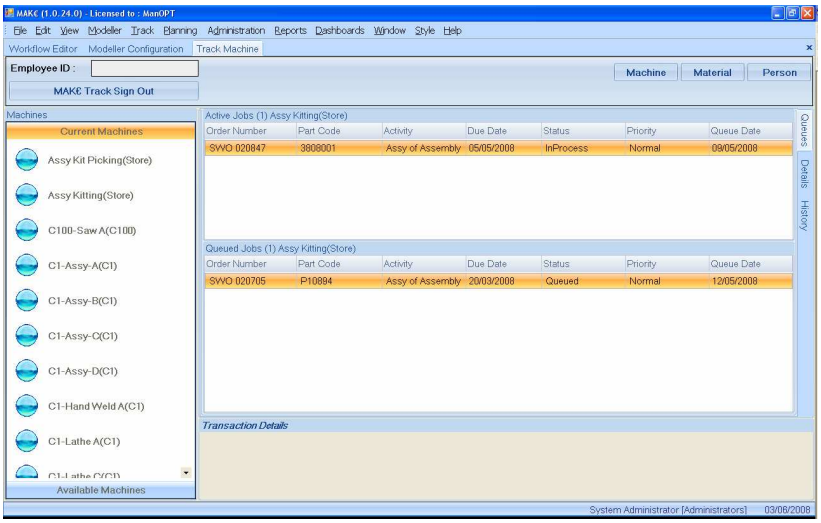


Figure 7.6: Work Tracking for each resource (person)

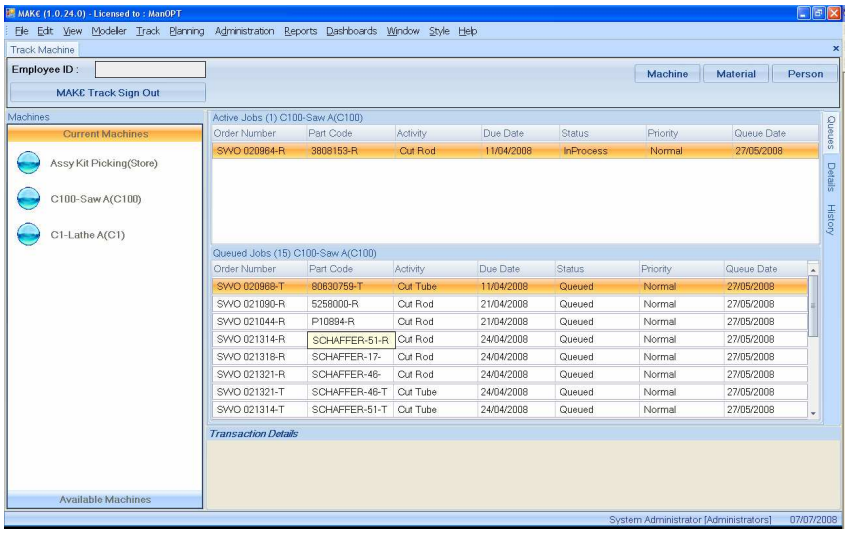


Figure 7.7: Work Tracking for each resource (machine)

System Deployment

The main role of the software development partner ManOPT was to take the concepts developed by the RTD partners, implement them in robust software code, test in a production environment and validate at the end-user sites. While the main work envisaged in the workplan was the integration of the different modules of the EMPOSME; in practise significant development effort was required to bring the RTD concepts to a robust state to be tested in a production environment. Modules also had to designed and built that were not envisaged in the workplan. The latter included:

- A **Work flow modeller** which facilitated
    - Editing all resources, states and activities that could exist in the system, including their parameters.
    - Editing the relationships between states, activities and resources; transactions between states, and alternates for execution.
    - Editing the calendar for single resources, combinations of resources.
    - Editing state and activity workflows.

  The reasons for extension of the meta-modelling concepts in WP3 have been previously discussed. (See section Enterprise Modelling for Performance Optimisation).

- A '**Track' module** to present 'to-do'lists to the end user as well as track the subsequent transactions thereon. From the additional interview conducted during P2, a number of reasons emerged as to why performance management was not used for running, controlling or optimising the SME enterprises. The primary reason was the lack of a practical, easy-to-use, operational, generic, performance measurement system suitable for SMEs and capable of tracking operational issues that were of common concern. Additional functionality was required in the Workflow modeller in any case to represent the dynamic nature of the SME states realtime to the optimiser. The next logical step was to close the loop and provide a module that would not only present the realtime state of the enterprise to the optimiser but would also provide the end-user with a view of the enterprise. Thus the inception of the Track module.

- The **EPM (Enterprise Performance Management)** module.

A key objective was to provide the users with an integrated software tool that provided a seamless user experience for the SME end-user. The following integration steps were completed:

1. Integration of the Enterprise Visualisation Tools (Performance Manager) with the Modeller and the Optimiser.
2. The confirmation that the Enterprise Model exchange representation enables the integration of the Enterprise Modeller and the EMPOSME Optimisation Software Builder.
3. Verification of the effective production quality of integration between all modules of the EMPOSME Project by deploying them in the SMEs partner sites.
4. Integration of the EMPOSME tool with legacy ERP systems at the end-user sites (additional to the workplan).

The initial evaluations of the toolkit were used to advance the functionality of the resulting software. In total 25 iterative builds were released to the end-user firms. In all cases requirements emerged from individual SME partners that had not been articulated in the initial requirements engineering. The focus was on ensuring that the additional features of the EMPOSME tool were implemented in a generic way so that they could be exploited by all of the SME partners.

Impact for SMEs in the consortium

The most critical impact of this project has been in the time based competitive capability of the end user SMEs. At the end of this project the end user SMEs using the EMPOSME tool have achieved the following Performance Outcomes:

- √ Sales Order Velocity increase of greater than 30%
- √ Sales Order On Time in Full (OTIF) Delivery Performance (as compared to original Order Promise date) increase to over 95% from the current estimated level of 40%.
- √ Reduce Planning Time by greater than 60% and Planning Effort by greater than 50%.

SME #1[1] (Full Deployment)

- reduced their sales order velocity from a range to 2-16 weeks to an average of 4 weeks
- improved their on-time-in-full shipments from a range of 40-90% to an average of 85%
- reduced planning time from 2 days a week (with hours for replanning when perturbations occurred) to 0.5 days per week with updates possible in 5 minutes.
- Their planning effort was reduced from 3 people to 2 people freeing up the Purchasing Manager from routine planning tasks.
- ***while at the same time doubling their production volume.***

SME #2 (Near Full Deployment)

- reduced their sales order velocity from 4 days to 3 days (while at the same time doubling their production volume).
- maintained their on-time-in-full shipments from a range of 95% to an average of 96% ***(while at the same time doubling their production volume)***
- reduced planning time from 4 days a week continuous planning to 1 day per week with updates possible in 15 minutes. Their planning effort was reduced by 25% for both the operations and production manager.

SME #3 (In the set-up phase, Full Deployment Planned)

- Improved operator utilisation via improved planning techniques.
- Additional training was provided in parallel to the project to create a more flexible work force to enable better departmental balancing.
- Jobs that could not be completed due to material shortages would not be started reducing WIP.
- The sales department has a much clearer view of what could be manufactured and when.
- Tracking of specific orders becomes much simpler through a manual tracking process.
- Team leaders roles are changed from reactive to proactive.
- Methods of tracking and agreeing change have been formalised and therefore become standard practice.

SME #4, #5 Contributed to Requirements Engineering and Evaluation of Demonstrations.

[1] SME names remain confidential for comemrical reasons. Identities available in cnfidentail reports to the EU.

The following tables summarise the performance outcomes of the SMEs prior and post EMPOSME implementation. It can be seen from Table 2 that the SMEs who utilised the EMPOSME Toolkit to the greatest extent made the most improvements (SME #1, #2). The firms operating a Make to Stock (MTS) policy SME #4, #5 did not exploit the EMPOSME toolkit to the same extent and therefore did not show the considerable improvements demonstrate by the other firms. It is important to note that the issue of order urgency is a key feature of the EMPOSME toolkit. The firms that are operating on a Make to Order (MTO) or a Engineer to Order (ETO) policy have a more critical need for the EMPOSME toolkit.

It is important to qualify at that the initial performance data from the SMEs was essentially an estimation by the SME practitioners together with market feedback. This should be kept in mind when reviewing performance outcomes since the actual achievements of the EMPOSME toolkit may be under or over estimated.

- *Sales Order Velocity increase of greater than 30%.*

  This performance metric measures the responsiveness of the SME to its customers. The EMPOSME tool particularly targeted non-value added queue time and thereby contributed to an enhanced customer experience. This goal has been achieved since providing a rapid service is a critical competitive capability for SMEs.

  This objective has successfully been achieved and exceeded as shown by the results in Table 2 for the firms that utilised the EMPOSME tool.

  SME #1 reduced their sales order velocity from a range to 2-16 weeks to an average of 4 weeks (while at the same time doubling their production volume).

  SME #2 reduced their sales order velocity from 4 days to 3 days (while at the same time doubling their production volume).

- *Sales Order On Time in Full (OTIF) Delivery Performance (as compared to original Order Promise date) increase to over 95% from the current estimated level of 40%.*

  This performance metric measures the reliability of the SME in delivering on its commitments to its customers. The EMPOSME tool enabled users that were particularly poor at order promising due to a lack of visibility of their prior resource commitments to improve both order promising, and also order velocity as above. This better sales order promising has contributed to an enhanced customer experience. This goal has been selected since providing a reliability of service is a critical competitive capability for SMEs.

  Once a customer commitment is given to deliver a particular sales order on a given date then it is essential that the operational resources of the enterprise are deployed effectively to achieve this outcome. The EMPOSME toolkit through the use of the Track feature greatly facilitates this performance outcome. This is a achieved by keeping the sales order and its prerequisite tasks on a todo list until it is successfully fulfilled to the customer.

  This objective has successfully been achieved and exceeded. This is shown by the results in Table 2 for the firms that utilised the EMPOSME tool.

  SME #1 improved their on-time-in-full shipments from a range of 40-90% to an average of 85% (while at the same time doubling their production volume).

SME #2 maintained their on-time-in-full shipments from a range of 95% to an average of 96% (while at the same time doubling their production volume).

- *Reduce Planning Time by greater than 60% and Planning Effort by greater than 50%.*

  An important barrier to growth of SMEs is the limit on highly skilled decision maker time. Currently a large portion of this time is allocated to the planning activity and is interspersed throughout a typically hectic day. The EMPOSME tool supports the decision maker get the task done in a reduced wall clock time as well as a reduced effort by the planner since he has all of the information at hand in close to real time.

  A critical contribution of the EMPOSME toolkit has been to support the decision makers within the SMEs. A most important feedback from the SME practitioners has been the sense of knowledge that they have about the true state of their enterprise at any given moment. The EMPOSME has not only achieved a dramatic time reduction for the SME practitioners, it has also increased the efficacy of their decision making since it has enabled them to be much more proactive. When the EMPOSME tool is used then they can see the issues that will impede their performance much earlier than with the prior approach.

  This objective has successfully been achieved and exceeded. This is shown by the results in Table 2 for the firms that utilised the EMPOSME tool.

  SME #1 reduced planning time from 2 days a week (with hours for replanning when perturbations occurred) to 0.5 days per week with updates possible in 5 minutes. Their planning effort was reduced from 3 people to 2 people freeing up the Purchasing Manager from routine planning tasks.

  SME #2 reduced planning time from 4 days a week continuous planning to 1 day per week with updates possible in 15 minutes. Their planning effort was reduced by 25% for both the operations and production manager.

The timing of the achievement of these objectives was slower than initially expected; however the total contribution of the EMPOSME toolkit has been much more effective than initially planned.

Baseline Performance	**SME #1**	**SME #2**	**SME #3**	**SME #4**	**SME #5**
Manufacturing Strategy	Make to Order (MTO)	Engineer to Order (ETO)	Make to Order (MTO)	Make to Stock (MTS)	Make to Stock (MTS)
Finished Goods Inventory	Minimal	Minimal	Minimal	Very Large	Large
Raw Material Inventory	High due to risk of stock out.	High due to risk of stock out.	High due to risk of stock out.	High due to risk of stock out.	High due to risk of stock out.
Sales order velocity	16 weeks	4 days	16 Weeks	4 Weeks	12 Weeks
OTIF (On-Time-In-Full)	40% - 90% estimate.	90% estimate	60% estimate	95% estimate	95% estimate
Planning Time	2 days per week for a weekly plan, plus adjustments throughout the week	Continuous shift basis 4 Mandays/week	3 days per week for a weekly plan, plus adjustments throughout the week	Continuous shift basis 8 Mandays/week	Continuous shift basis 6 Mandays/week
Planning Effort	3 people = 2 people / 4 mandays per week for material. = 1 person / 2 mandays for capacity.	25% of operations manager time 25% of production manager	70% of Managing Directors time 90% of production manager	90% of operations manager time 90% of production manager	90% of operations manager time 90% of production manager

Table 1 Performance Prior to EMPOSME Project

Baseline Performance	**SME #1**	**SME #2**	**SME #3**	**SME #4**	**SME #5**
EMPOSME Level of Exploitation	High	High	High	Low	Low
Sales Volume	Two Fold Increase	Two Fold Increase		20% in	
Raw Material Inventory	Reduced due to less risk of stock out.	High due to risk of stock out.	Reduced due to less risk of stock out.	High due to risk of stock out.	High due to risk of stock out.
Manufacturing Strategy	Make to Order (MTO)	Engineer to Order (ETO)	Make to Order (MTO)	Make to Stock (MTS)	Make to Stock (MTS)
Finished Goods Inventory	Minimal	Minimal	Minimal	Very Large	Large
Sales order velocity	4 weeks Reduced from 16 weeks	3 Days Reduced from 4 days	4 Weeks Reduced from 16 weeks	4 Weeks	12 Weeks
OTIF (On-Time-In-Full)	>85%	>96%	>80%	95% estimate	95% estimate
Planning Time	0.5 days per Mandays/week	0.25 Mandays/week	1 days per week for a weekly plan, plus adjustments throughout the week	Continuous shift basis 8 Mandays/week	Continuous shift basis 6 Mandays/week
Planning Effort	80% of effort focused on issue resolution rather than preparing planning data.	80% of effort focused on issue resolution rather than preparing planning data.	80% of effort focused on issue resolution rather than preparing planning data.	90% of operations manager time 90% of production manager	90% of operations manager time 90% of production manager

Table 2 Performance outcomes during EMPOSME Project

EMPOSME and ERP5

ERP5 is an open source ERP which is used by large companies and organizations such as EADS Astrium, the Central Bank of West Africa, the French Water Agency, etc. Its unsurpassed flexibility and wide functional coverage have made it the open source ERP of choice for complex or large scale mission critical applications. However, until very recently, ERP5 was not suitable for SMEs because its unsurpassed flexibility also meant a steeper learning curve for implementers and thus configuration costs which could not match the budget of a small company.

It had been identified at P1 that the deployment of the existing form of the ERP5 system was limited by the configuration complexity for the End-User of the ERP5 application. The Nexedi Software Development partner devoted a considerable effort to increasing the ability of manufacturing practitioners from SMEs to configure the ERP5 application. This is a stated objective of the EMPOSME project that the resulting suite of tools can be used by practitioners. As part of this work they have developed Business Templates which provide pre-packaged business process steps for common business activities that are common with SMEs. These business templates are designed to integrate with the Enterprise Models.

The EMPOSME project has significantly contributed to the progress of ERP5 towards SMEs through two major achievements:

- the "Business Template" technology which provides a base abstraction of corporate information system. ;
- the "ERP5 Express Wizard" technology which automates the configuration of business templates to meet SMEs requirements.

ERP5 is now available to all SMEs for free as a hosted application, a.k.a. Software as a Service (SaaS) under the name "ERP5 Express". A factory in Poland - "Ventis[2]" - which has acted as a testbed for ERP5 Express in the field of manufacturing, significantly improved its operations through the implementation of ERP5. At the time of submitting this deliverable report, there are more than 1025 registered subscribers, with an estimate of 150 functional SMEs. The breakdown is as follows.

France	20.70%
United States	5.00%
Brazil	3.70%
Canada	2.30%
Poland	2.00%
Portugal	2.00%
Germany	1.30%
Italy	1.10
UK / N. Ireland	1.00
Switzerland	0.90
Belgium	0.80
Romania	0.80
Spain	0.70
Netherlands	0.50
Norway	0.50
Sweden	0.50
Bulgaria	0.40
Greece	0.40
Hungary	0.30
Ireland	0.30
Austria	0.20

[2] Ventis are not a partner in the EMPOSME project. As discussed earlier the SMEs in the consortium opted to retain their legacy systems. The lack of an demonstrator SME for ERP5 was highlighted in the P1 Review Report. Ventis, a Polish SME, have acted as a demonstrator of the ERP5 system

Business Templates (bt5)

Business Templates is the base abstraction in ERP5 to encapsulate in a distributable file the know-how which relates to the implementation of ERP type business applications. A business template consists of:

- A list of document types (ex. product, invoice)
- A list of presentation forms (ex. product definition form, invoice input form)
- A list of workflows (ex. product validation workflow, Sarbane Oxley workflow)

The business technology was created during the first phase of the EMPOSME project and was then used to transfer the know how of Nexedi staff into XML files during the second phase of the EMPOSME project. More than 5 million lines of XML have been produced to cover the basic needs of an SME in terms of production management. The following business templates are now simple and mature enough for an SME to quickly configure ERP5 to its needs:

- erp5_base: management of currencies, people and organizations ;
- erp5_trade: management of products, components, inventory, purchase, sales and logistics ;
- erp5_pdm: design of a product in terms of Bill of Material (BOM) and Bill of Operations ;
- erp5_mrp: simulation, prevision and calculation of material requirements ;
- erp5_accounting: accounting and invoicing ;
- erp5_crm: customer relation management ;
- erp5_dms: document management (ex. ISO 9000 procedures).

All business templates were tested by an SME - "Ventis" - located in Poland and implemented for the management of a factory of photographic components. ERP5 has now replaced tedious spreadsheet based management systems and has helped Ventis to drastically improve its operations.

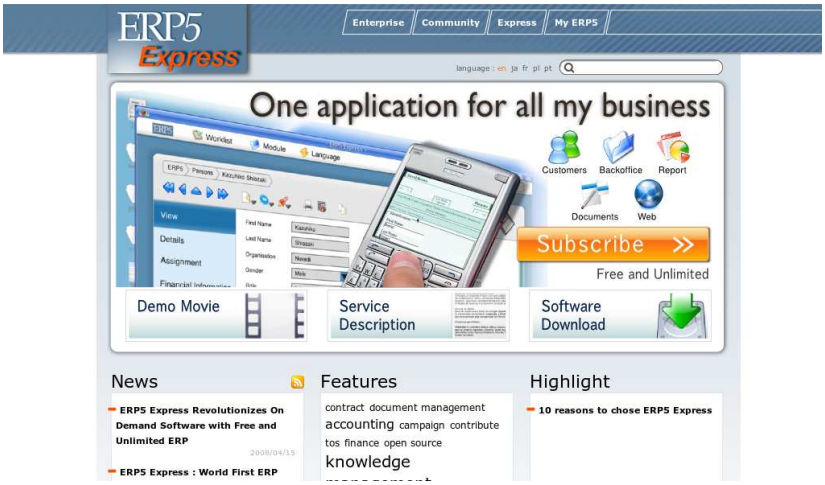
Configuration Wizard

During the second phase of the EMPOSME project, Nexedi tried to automate the configuration process of ERP5 so that the time between the first installation of ERP5 and the first use of ERP5 by factory workers could be drastically reduced. The goal was to reduce a 1 year process to a process of 5 minutes.

This goal mostly reached. Nexedi developed a set of tools, called "ERP5 Wizard" which automatically generate a custom business template out of business requirements entered by the user. For example, a company can select the language of the application, the accounting system, the number of sites, the type of business, the nomenclatures, etc. Based on this input, "ERP5 Wizard" selects the most appropriate configuration options and stores them in a business template which is unique to each company.

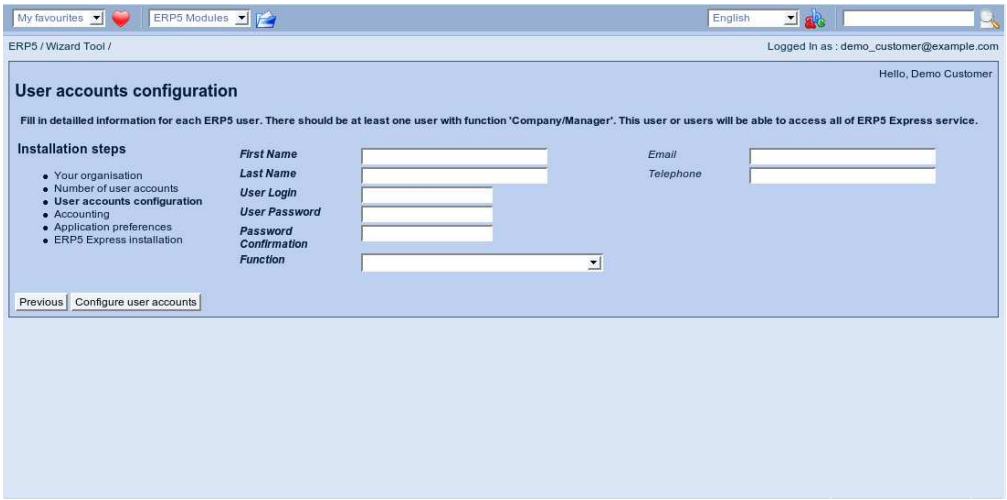
This allows to install and have a ready to use "standard" ERP5 instance in less than 5 minutes, at which point the instance becomes fully operational. The time it takes for initial functionality depends on the level of complexity of the existing enterprise, for instance data migration, or switching from another system may take longer. Typically, when such customization is required, it takes up to one year to deploy the complete business fields with ERP5. In the case of the Polish company a year was enough to get initial functionality going (including analyzing, configuring every application separately, testing, training, data migration, support, etc.).

The combination of the work achieved during Phase I and the work achieved during Phase II can be experienced through the "ERP5 Express" service:



http://www.myerp5.com

In this service, a company first subscribes to ERP5 Express by providing its contact information. Once the contact information has been validated, Nexedi generates automatically a new ERP5 instance on its servers and provides login information to the subscriber. The subscriber then logs into its ERP5 instance.



The subscriber then enters company specific information and after less than 5 minutes, the "ERP5 Wizard" does the following steps:

1. Install all business templates required to meet the customer requirements (ex. erp5_pdm)
2. Generate a business template to encapsulate all customer specific configuration
3. Install this customer specific business template

ERP5 is then ready to be used by the subscriber.

Thanks to the ERP5 Configuration Wizard, ERP5 is now easy enough to configure for SMEs to use it. A beta program for a future commercial service was launched in April 2008 by Nexedi. In less than 3 months, 1000 companies subscribed to it. It clear demonstrates that the combination of business templates and of Configuration Wizard was the missing component for SMEs to adopt a high solution such as ERP5.

Plan for using and disseminating the knowledge

The following is an extract from the EMPOSME Consortium agreement outlining the ownership of results:

Each Party is bound by the terms and conditions of the European Commission contractual Rules, which are hereby made an integral part of the present Consortium Agreement:

1. *Annex II General Conditions - Part C entitled "Intellectual Property Rights ",*
2. *Annex III "Specific IPR Provisions for Cooperative Research Actions" as hereby complemented.*

Knowledge is owned by the SME Partners as from day one of its creation and the transfer is deemed operated to SME by the RTD Performers who accept to enter into any additional agreement if necessary in particular for the purpose of complying with the copyrights laws of the different countries concerned. Except for that last purpose, no formal additional transfer of ownership is necessary from RTD Performers. The Parties hereby acknowledge and agree that all and any Knowledge will be the sole and exclusive property of the SME Partners subject to the following allocation of rights:

SME End-Users:

The SME End Users have the right to use and exploit the knowledge through the use of the resultant software products. They do not have the right to sub-license the resultant software.

SME Developers:

The software will be made available to an open-source software community through GPL Open Source / Libre Software License (except where restricted through the use of third party software).

The SME Developers own all Commercialisation Rights to the resultant knowledge.

Exploitation of Results

The consortium has at all times been aware that a key objective of publicly-funded CRAFT research is that it should lead to the exploitation of results. The academic partners have been very active in the in the publication and dissemination of new scientific knowledge.

FIRA has been actively disseminating the non-confidential aspects of this project to its membership base and beyond. Basic information is displayed on the furniture industry web portal www.askFIRA.co.uk. A promotional strategy is being developed that will maximise the coverage of the EMPOSME tool throughout the EU furniture sector. This strategy will subsequently be transferred into other manufacturing sectors through FIRA's relationship network with other RTDs.

The SME partners are strong advocates of the Treaty objective of "strengthening the scientific and technological bases of Community industry while *encouraging it to become more competitive at international level"*. They have identified that the key competitive imperative for them to compete in the international arena is to provide their products to their customers 'on-time-in-full'. The EMPOSME prototype tool enables them to meet that objective. Indeed, adopting such a strategy has enabled one of the SME partners to double their sales without adding any additional resources.

The plans for commericalisation are currently being formulated by the SME software developer partners, ManOPT Systems Ltd. and Nexedi SARL.

Section 1 - Exploitable knowledge and its Use

The primary objective of this consortium, to develop and implement an Enterprise Modelling and Performance Optimisation (EMPOSME) tool, was achieved during the second project period P2. The final EMPOSME suite of tools, as validated through deployment at the SME end-user sites, is used as follows (and described in Figure 1,2):

(1) The end user interacts with the **Enterprise Modeller** to describe (or model's) the entities in the organisation at enterprise level relevant to the main Key Performance Indicator. The data for the Supply-Demand Position is extracted real-time from the ERP system and / or legacy databases such as spreadsheets.

(2) The **Optimisation and Planning Module** then plans multiple resources vis-à-vis a suite of Key Performance Indicators. The plan is integrated, e.g. unlike standard planning systems the material optimisation does not assume infinite capacity and vice versa. The plans also allow for user interaction so that the practitioner can use his/her empirical experience to adjust the plan using visual interfaces to display the consequence of his/her decision on the relevant performance indicator.

(3) The **Performance Manager** shows the impact of the planning decisions taken today on the Key Performance Indicator (Predictive Performance Planning). For example a series of visually interactive screens show the predictive performance of the enterprise based on the plan produced. The decision maker can thus rapidly identify the risk/reward position of any choice he has to make vis-à-vis a suite of defined key performance indicators.

The primary result of this project is the EMPOSME system / tool. EMPOSME integrates **Enterprise Modelling** and **Enterprise Optimisation** so that the decision maker can rapidly identify the risk/reward position of any choice **(decisions)** he has to make vis-à-vis a suite of defined **key performance indicators.**

The **EMPOSME tool** enables the experienced practitioner within an SME to accomplish the following:

- Rapidly model and accurately represent all of the Entities (e.g. sales orders) and Resources (e.g. People and Machines) within the typical firm via a visually appealing user Interface.
- Enable the practitioner to define his multi-criteria Enterprise Objective function or goal.
- Enable the manager to rapidly diagnose and resolve the myriad of resource conflicts that emerge frequently within an enterprise.
- Enable the manager to evaluate the proposed solution and deploy it to people that complete the value generation activities within the firm.
- To develop and implement an integrated software solution to achieve an 'holistic optimised resource allocation solution' needed to process all sales orders in MTO and ETO industries for a near-optimum solution from initial quotation to return of the product at the end of its useful life.

At the end of this project the end user SMEs using the EMPOSME tool have achieved the following Performance Outcomes:

- √ Sales Order Velocity increase of greater than 30%
- √ Sales Order On Time in Full (OTIF) Delivery Performance (as compared to original Order Promise date) increase to over 95% from the current estimated level of 40%.
- √ Reduce Planning Time by greater than 60% and Planning Effort by greater than 50%.

The following table, from the DoW page 29, shows the main project outputs and indicate the range of applications as well as the targeted user groups, the impact and the time range to exploitation:

Nexedi and ManOPT will commercially market these results. For this purpose ManOPT is the exploitation manager for the project. The role of the exploitation manager is to co-ordinate all the aspects which have any influence on the exploitation of the results, by co-operating with technical and commercial staff of all the partners. She will co-ordinate all exploitation related issues within the Consortium (patents, licenses, dissemination activities, etc.). She will also be in charge of co-ordinating possible negotiations concerning exploitation issues between the Consortium and external third parties.

Since the Open Source Business Model for the Enterprise Modeller will be used the consortium expects that there will be a high take up rate by SMEs since there are no barriers to entry. It is expected that this will encourage firms to try to build an Enterprise Model and when they see the opportunity for further improvement they will then either buy or use the web service to optimise their manufacturing facility.

EXPECTED RESULTS AND EXPLOITATION				
Project output/ Result	**Range of Applications**	**Expected Impact**	**Timing**	**Partner(s) responsible For exploitation**
Community Added Value:				
EMPOSME system	Discrete manufacturing processes	Improving competitiveness and collaboration among European companies	End of project	ManOPT / Nexedi
Social / Environmental Impact:				
EMPOSME system	Discrete manufacturing processes	Improving quality of life of managers Improving work conditions and operators skills The use of Open Source based tools will help the development of Information Society	1-2 years	ManOPT / Nexedi
Performance Optimisation module	Discrete manufacturing processes	WASTE REDUCTION, ENERGY SAVINGS	End of project	ManOPT
Technical / Economic Impact:				
EMPOSME system	Discrete manufacturing processes	Lead-time and planning time reduction, more efficient use of resources, more reliable production time forecast, faster response	End of project	ManOPT / Nexedi
Performance Optimisation module	Discrete manufacturing processes	Cost savings due to reduction in resource consumption and increased SME End User customer satisfaction.	End of project	ManOPT

Section 2 – Dissemination of knowledge

Thus far, the knowledge generated from, and as side ground to, the EMPOSME project has been published as follows:

Workshops and Public Dissemination Events

Enterprise Ireland hosted a series of information seminars, in the various Irish regions, during 2007-2008, highlighting the opportunities and support structures for Irish SMEs to become involved in projects within the EU 7th Framework Programme. UL and ManOPT were active participants in these seminars using EMPOSME as a case study to promote involvement in FP7. The seminars included topics such as:

"Benefits of and how to get involved in an FP7 Consortium - An industrial SME Perspective" by Ann Sheahan, Manopt Systems Ltd, Limerick, Friday, 7th December 2007 at the Rubicon Centre CIT, Cork.

"An EU FP6 Project Coordinator's perspective" by Dr. Con Sheahan, Enterprise Research Centre, University of Limerick , Tuesday, 16th January 2007 at the Castletroy Park Hotel, Limerick

"Opportunities for SMEs within FP7" - A briefing to Galway Chamber of Commerce; by Ann Sheahan, Manopt Systems Ltd, Limerick Wednesday, 5th March 2008.

SMEs Connecting with Framework Programme 7 - Wednesday 2nd May, 2007 in Limerick, included presentations by:

"Experiences of an Irish SME in FP6, Plans for FP7" by Ann Sheahan, ManOPT Systems Ltd.,
"Experiences of a Co-Ordinator in FP6 CRAFT" by Con Sheahan, Researcher, University of Limerick.

ManOPT, was invited by the National Director for FP7, and attended a workshop on behalf of Enterprise Ireland and the FP7 National Support Network on Thursday May 10th 2007 at the Radisson Hotel, Athlone. This workshop involved SME's from around the country brought together to discuss their views and opinions on involvement in the EU Framework Programme 6 (FP6). In particular, the following were addressed: Perceived benefits and opinions on FP6 SME funding in Ireland and Views and opinions on the upcoming FP7 programme.

ManOPT also presented to Enterprise Ireland Tech Club (December 13th 2006) on the experiences in FP6.

ManOPT will attend and present a poster at:

French presidency of the Council of the European Union
CONSOLIDATING RESEARCH AND INNOVATION FOR EUROPEAN SMES
How to do more and better?
MONDAY 15 AND TUESDAY 16 SEPTEMBER 2008
Paris (France) , Ministry of the Economy, Industry and Employment

University of Limerick

Publications

Sheahan, A; Sheahan, C. (2006) " ENTERPRISE MODELLING AND PERFORMANCE OPTIMISATION FOR SMES (EMPOSME)" (PMA) Performance Measurement and Management: Public and Private 25-28 July 2006, Cranfield School of Management, London, UK.

Wilson, C., Sheahan, C. (2006) State of Performance Measurement Practice in SMES. (PMA) Performance Measurement and Management: Public and Private 25-28 July 2006, Cranfield School of Management, London, UK pg 809-816.

Dang Thanh-Tung, Ben Flood, Cáthál Wilson, Con Sheahan: Ontology - MAS for modelling and robust controlling enterprises. *The First International Conference on Theories and Applications of Computer Science (ICTACS'06), August 3rd - 5th, 2006,* published by World Scientific, ISBN 978-981-270-063-6, pp 116 – 123.

Dang Tung, Cáthál Wilson and Con Sheahan: MAS for modelling dynamic manufacturing systems. *The international Conference on Modelling of Complex Systems and Environments, July 2007, ISBN: 978-0-9763486-3-4, pp. 116 – 120*.

Dang Thanh-Tung, Cáthál Wilson, Ben Flood, Con Sheahan: Using Ontology to help achieve mobile, multi-skilled employees *The First International Conference on Theories and Applications of Computer Science (ICTACS'06), August 3rd - 5th, 2006,* published by World Scientific, ISBN 978-981-270-063-6, pp. 7 – 16.

Joint publications with the other RTD partners are listed under the leading RTD partner below (to avoid duplication).

Aalborg Uniiversitet

Publications

Trienekens, J; Hvolby, H-H; Steger-Jensen, K; Falster, P; Verdouw, C. "Review of reference models for Supply Chain Modelling". In proceedings of the APMS conference, Poland, September 2006. ISBN 837-085-971-2.

Hvolby, H-H 1; Thorstenson, A: "Focused versus diversified logistics performance measurement in small and medium-sized enterprises". In proceedings of the 11th World Congress of Total Quality Management, New Zealand, December 2006

Publications with UL

Hvolby, Hans-Henrik; Steger-Jensen, Kenn; Gulledge, Thomas; Sommer, Ray; Sheahan, Con: "Supply Chain Integration Solutions"", Proceedings of the APMS conference, Washington DC, September 2005.

Gulledge, T; Hvolby, H-H; Sheahan, C; Sommer, R & Steger-Jensen, K. "Supply Chain Integration: State-of-the-Art, Trends and Challenges" in "Advanced Manufacturing - An ICT & Systems Perspective" edited by Taisch & Thoben), Taylor & Francis Group, 2007. s. 283-288.

Gulledge, T; Hvolby, H-H; Sheahan, C; Sommer, R & Steger-Jensen, K. "Supply Chain Integration: State-of-the-Art, Trends and Challenges" in "Advanced Manufacturing - An ICT & Systems Perspective" edited by Taisch & Thoben), Taylor & Francis, 2006 (in press).

Website

A web site for the work developed in this work package can be seen at:

http://vbn.aau.dk/research/emposme_enterprise_modeling_and_performance_optimisation_for_smes(6977387)/

Univerzita Karlova v Praze

The EMPOSME project contributed significantly to ongoing research at Charles University in several ways. First, the EMPOSME project is a continuation of research done by the CLP group at Charles University in recent years. This research focused on developing constraint satisfaction technology for solving integrated planning and scheduling problems and the achieved results are now capitalised and strengthen in the EMPOSME project. Note that we focus both on formal problem modelling and on problem solving. Second, the EMPOSME project gives us access to SMEs and provides real-life data to validate the developed technology and to apply it in real-life setting. This is critical because in cooperation with industry, we can propose formal models that fit real requirements. Hence the project bridges the traditional gap between industry and academia. Finally, the project gives opportunity for exchanging knowledge between research partners, both in the area of our expertise (Cork Constraint Computer Centre) and in other related areas like manufacturing (University of Limerick) and enterprise modelling (Universitaet Duisburg-Essen).

Contribution to research

The EMPOSME project contributed significantly to ongoing research at Charles University in several ways. First, the EMPOSME project is a continuation of research done by the CLP group at Charles University in recent years. This research focused on developing constraint satisfaction technology for solving integrated planning and scheduling problems and the achieved results are now capitalised and strengthen in the EMPOSME project. Note that we focus both on formal problem modelling and on problem solving. Second, the EMPOSME project gives us access to SMEs and provides real-life data to validate the developed technology and to apply it in real-life setting. This is critical because in cooperation with industry, we can propose formal models that fit real requirements. Hence the project bridges the traditional gap between industry and academia. Finally, the project gives opportunity for exchanging knowledge between research partners, both in the area of our expertise (Cork Constraint Computer Centre) and in other related areas like manufacturing (University of Limerick) and enterprise modelling (Universitaet Duisburg-Essen).

Publications

Temporal models of resources

- **Constraint Models for Complex State Transitions**
  R. Barták, In Computer Assisted Mechanics and Engineering Sciences (CAMES) Journal, Vol. 14, No. 4, pp. 543-555, 2007.
- **A Constraint Model for State Transitions in Disjunctive Resources**
  R. Barták, O. Cepek. Recent Advances in Constraints, LNAI 4651, Springer-Verlag, 2007, pp. 48-62.
- ***A Constraint Model for State Transitions in Disjunctive Resources***
  R. Barták, O.Cepek. In Proceedings of the 11th ERCIM Workshop on Constraint Solving and Constraint Logic Programming (CSCLP 2006), pp. 217-230, 2006.
- ***A Constraint Model for State Transitions in Disjunctive Resources***
  R. Barták, O.Cepek. In Proceedings of the 5th International Workshop on Planning and Scheduling for Space (IWPSS 2006), pp. 278-285, 2006.
- **Incremental Maintenance of Double Precedence Graphs: A Constraint-Based Approach**
  R. Barták, O.Cepek. In Proceedings of The Sixteenth International Conference on Automated Planning and Scheduling. (ICAPS 2006), AAAI Press, pp. 350-353, 2006.
- **Incremental Propagation of Time Windows on Disjunctive Resources**
  R. Barták. In Proceedings of the Nineteenth International Florida AI Research Society Conference (FLAIRS 2006). AAAI Press, pp. 25-30, 2006.

Integrating temporal and logical reasoning

- **Incremental Filtering Algorithms for Precedence and Dependency Constraints**
  R. Barták, O. Cepek. In International Journal on Artificial Intelligence Tools, to appear in April 2008.
- ***Incremental Filtering Algorithms for Precedence and Dependency Constraints***
  R. Barták, O.Cepek. In Proceedings of the 18th IEEE International Conference on Tools with Artificial Intelligence (ICTAI 2006). IEEE Press, 2006, pp. 416-423.
- ***Incremental Filtering Algorithms for Precedence and Dependency Constraints***
  R. Barták, O.Cepek. In Proceedings of the CP 2006 Workshop on Constraint Propagation And Implementation (CPAI 2006), pp. 3-18, 2006.

Model integration

- **From Enterprise Models to Scheduling Models: Bridging the Gap**
  R. Barták, J. Little, O. Manzano, C. Sheahan. In Miguel A. Salido, Juan Fdez-Olivares (Eds.) Planning, Scheduling and Constraint Satisfaction, Universidad de Salamanca, pp. 44-56, 2007. (ISBN-13: 978-84-611-8860-4).

Temporal networks with alternatives

- **Nested Temporal Networks with Alternatives: Recognition and Tractability**
  R. Barták, O. Cepek. Applied Computing 2008 - Proceedings of 23rd Annual ACM Symposium on Applied Computing, Volume 1, pp. 156-157, ACM, (ISBN 1-59593-753-7) to appear in March 2008.
- **Temporal Reasoning in Nested Temporal Networks with Alternatives**
  R. Barták, O. Cepek, M. Hejna. In Znalosti 2008, to appear in February 2008
- **Nested Temporal Networks with Alternatives**
  R. Barták, O. Cepek. In Hans W. Guesgen, Gerard Ligozat, Jochen Renz, Rita V. Rodriguez (Eds.): Papers from the 2007 AAAI Workshop on Spatial and Temporal Reasoning, Technical Report WS-07-12, AAAI Press, 2007, pp. 1-8 (ISBN: 978-1-57735-339-3)
- **Generating Implied Boolean Constraints via Singleton Consistency**
  R. Barták. In Abstraction, Reformulation, and Approximation (SARA 2007), LNAI 4612, Springer-Verlag, 2007, pp. 50-64.
  Also in Proceedings of ERCIM Workshop on Constraint Solving and Constraint Logic Programming (CSCLP 2007), 2007, pp. 33-46.
- **Discovering Equivalence Classes in Precedence Graphs**
  R. Barták, O. Cepek, P. Surynek. In Peter Mikulecký, Jirí Dvorský, Michal Krátký (Eds.): Znalosti 2007. VŠB Ostrava, 2007, pp. 17-28 (ISBN: 978-80-248-1279-3).
- **Temporal Networks with Alternatives: Complexity and Model**
  R. Barták, O. Cepek. Proceedings of the Twentieth International Florida AI Research Society Conference (FLAIRS 2007). AAAI Press, 2007, pp. 641-646 (ISBN 978-1-57735-319-5).
- **Modelling Alternatives in Temporal Networks**
  R. Barták, O. Cepek, P. Surynek. Proceedings of the 2007 IEEE Symposium on Computational Intelligence in Scheduling (CI-Sched 2007), IEEE Press, 2007, pp. 129-136 (ISBN: 1-4244-0698-6)
- **Modelling Alternatives in Temporal Networks**
  R. Barták, O. Cepek, P. Surynek, Proceedings of The 25th Workshop of the UK Planning and Scheduling Special Interest Group (PlanSIG 2006), University of Nottingham, 2006, pp. 121-128.

Universitaet Duisburg-Essen

Publications

Jung, J., Sprenger, J.; "Enterprise Modelling in the Context of Manufacturing - Outline of an Approach Supporting Production Planning", ICB-Research Report, Institut für Informatik und Wirtschaftsinformatik (ICB), No. 23, 2008.

http://www.icb.uni-due.de/fileadmin/ICB/research/research_reports/ICB_Report_No23.pdf

Website

A web site for the work developed in this work package can be seen at:

http://www.wi-inf.uni-due.de/FGFrank/index.php?lang=en&&groupId=1&&contentType=Project&&projId=14

Cork Constraint Computer Centre 4C

Publications

4C, UL and Karlova also carried out dissemination activities through two conference papers.

Roman Barták, James Little, Oscar Manzano, Con Sheahan: **From Enterprise Models to Scheduling Models: Bridging the Gap** CAEPIA 2007, Workshop on Planning, Scheduling and Constraint Satisfaction.

This paper has been selected to be published in a special issue of the Journal of Intelligent Manufacturing (indexed in JCR-SCI)

<http://www.springer.com/east/home?SGWID=5-102-70-35668245-0&changeHeader=true&referer=www.wkap.nl&SHORTCUT=www.springer.com/prod/j/0956-5515>

"Enhancing Enterprise Information with Scheduling Components" James Little, Oscar Manzano, AlfioVidotto and Roman Bartak, submitted to 10th International Conference on Enterprise Information Systems, 12 - 16, June 2008, Barcelona, Spain.

Website

A web site for the work developed in this work package can be seen at:
http://4c.ucc.ie/web/projects/empo/index.html#

Section 3 - Publishable results

End Result : EMPOSME Tool

The primary objective of this consortium, to develop and implement an Enterprise Modelling and Performance Optimisation (EMPOSME) tool, was achieved during the second project period P2. The final EMPOSME suite of tools, as validated through deployment at the SME end-user sites, is used as follows (and described in Figure 1,2):

(1) The end user interacts with the **Enterprise Modeller** to describe (or model's) the entities in the organisation at enterprise level relevant to the main Key Performance Indicator. The data for the Supply-Demand Position is extracted real-time from the ERP system and / or legacy databases such as spreadsheets.

(2) The **Optimisation and Planning Module** then plans multiple resources vis-à-vis a suite of Key Performance Indicators. The plan is integrated, e.g. unlike standard planning systems the material optimisation does not assume infinite capacity and vice versa. The plans also allow for user interaction so that the practitioner can use his/her empirical experience to adjust the plan using visual interfaces to display the consequence of his/her decision on the relevant performance indicator.

(3) The **Performance Manager** shows the impact of the planning decisions taken today on the Key Performance Indicator (Predictive Performance Planning). For example a series of visually interactive screens show the predictive performance of the enterprise based on the plan produced. The decision maker can thus rapidly identify the risk/reward position of any choice he has to make vis-à-vis a suite of defined key performance indicators.

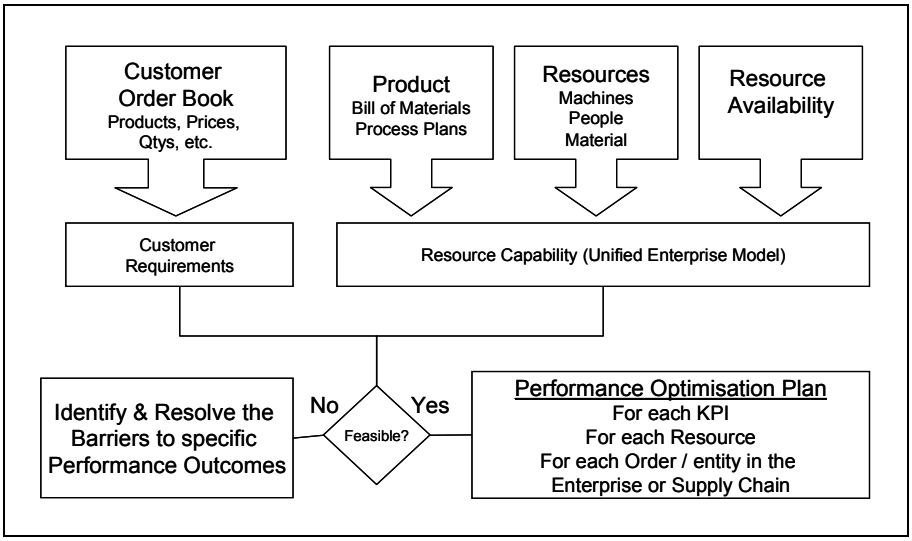


Figure 1: Overview Description of the Enterprise Model for the OTIF KPI

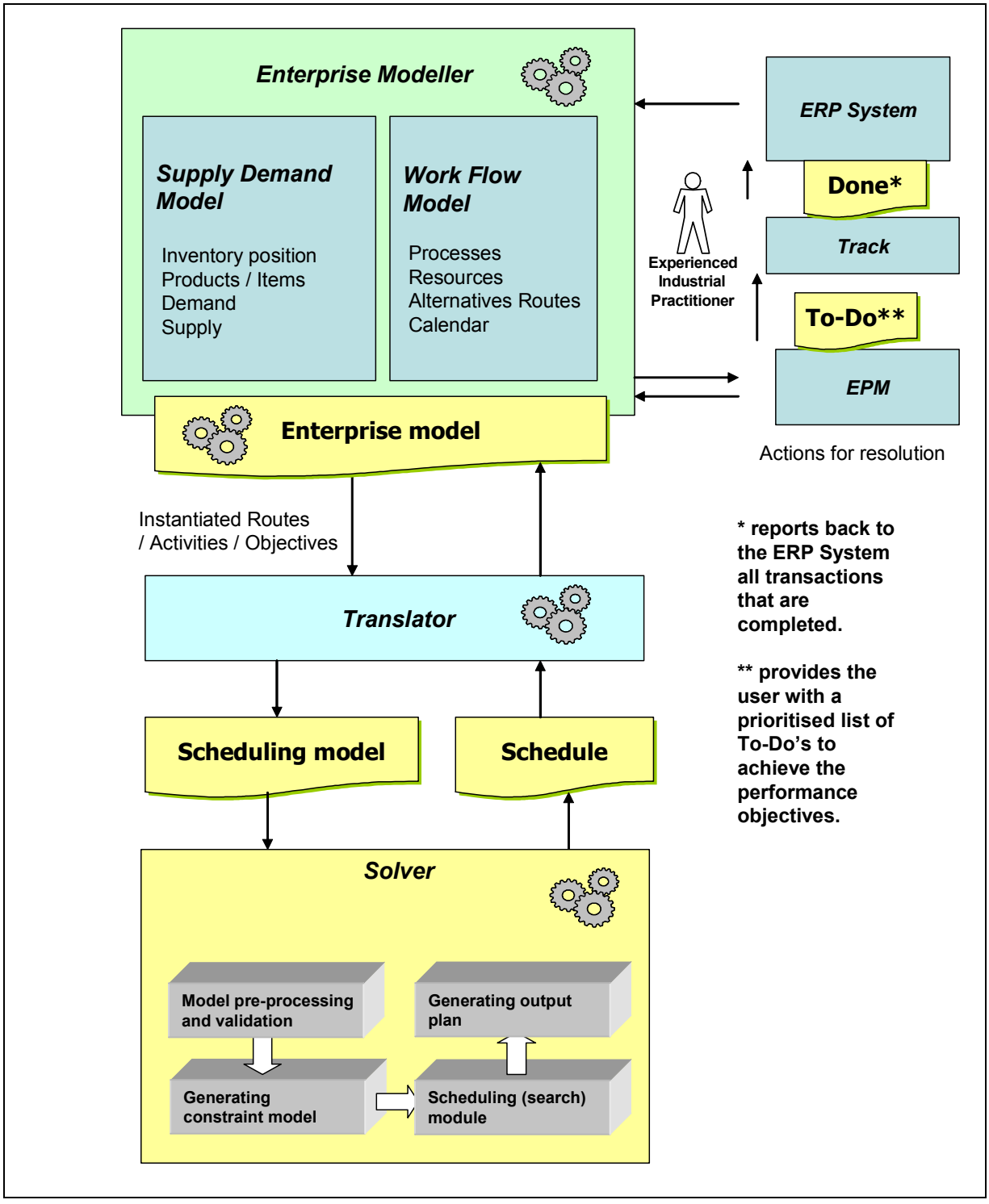


Figure 2 EMPOSME System Architecture as implemented