

Discrete Part Manufacturing Energy Efficiency Improvements with Modelling and Simulation

Juhani Heilala¹, Marja Paju¹, Jari Montonen¹, Reino Ruusu¹, Mikel Sorli², Alberto Armijo², Pablo Bermell-Garcia³, Simon Astwood³, Santiago Quintana³

¹VTT Technical Research Centre of Finland, Espoo, Finland
{juhani.heilala,marja.paju,jari.montonen,reino.ruusu}@vtt.fi

²Tecnalia, Bilbao, Spain

{mikel.sorli, alberto.armijo}@tecnalia.com

³EADS Innovation Works, Filton, Bristol, United Kingdom
{pablo.bermell-garcia,simon.astwood,santiago.quintana}@eads.com

Abstract. Energy efficiency has become a key concern in industry due to increased energy cost and associated environmental impacts. It is as well factor on marketing and reputation. Customers require information on the ecological performance of products and the process to build that product. Therefore eco-efficient manufacturing is in our days a matter of competitiveness and economic success. This paper presents industrial driven research and the key findings from production eco and energy efficiency analysis and development projects. Both static and dynamic multi-level modelling and simulation is covered with examples. The use of Value Stream Mapping and Discrete Event Simulation with life cycle inventory data for production eco efficiency analysis is explained. Generic development steps for process, machine and production system model with environmental aspects is shown. Development continues in EPES “Eco Process Engineering System for Composition of Services to Optimise Product Life-Cycle”- project.

Keywords: Energy efficiency, modeling and simulation, manufacturing



Discrete Part Manufacturing Energy Efficiency Improvements with Modelling and Simulation

Juhani Heilala, Marja Paju, Jari Montonen, Reino Ruusu @ VTT

Mikel Sorli, Alberto Armijo @ Tecnalia

Pablo Bermell-Garcia, Simon Astwood, Santiago Quintana @ EADS

APMS conference 24-26 September 2012, Rhodes Island Greece

Presented by Juhani Heilala, VTT

Outline

- EPES* project and objectives
- Sustainability intelligence
- Challenges
- Examples and State-of-the Art
- EPES System overview
- EPES Simulation
- Summary

*Eco-Process Engineering System For Composition of Services to Optimize Product Life-cycle





EPES project will develop, within the frame of the **Virtual Factory** concept, a **collaborative ICT tool** supported by a **methodology** and a working handbook, which will provide **dynamic services to optimize the product life-cycle management**, specially the **product manufacturing and operation phase** (maintenance and upgrades), with a focus on sustainability

- September 2011- August 2014 (36 months)
- www.epes-project.eu

Business Cases

- EPES Project development is **end-user driven**
- **Three business cases** will be developed:

TAM: Windmill engineering.
Optimization of the maintenance practices to increase turbines availability



NKT: Power cables provider. More efficient and safe transfer of distributed energy



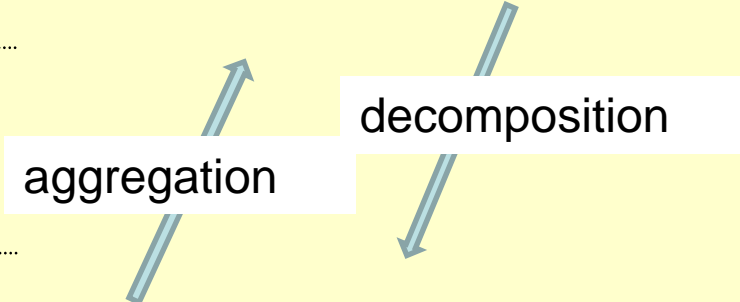
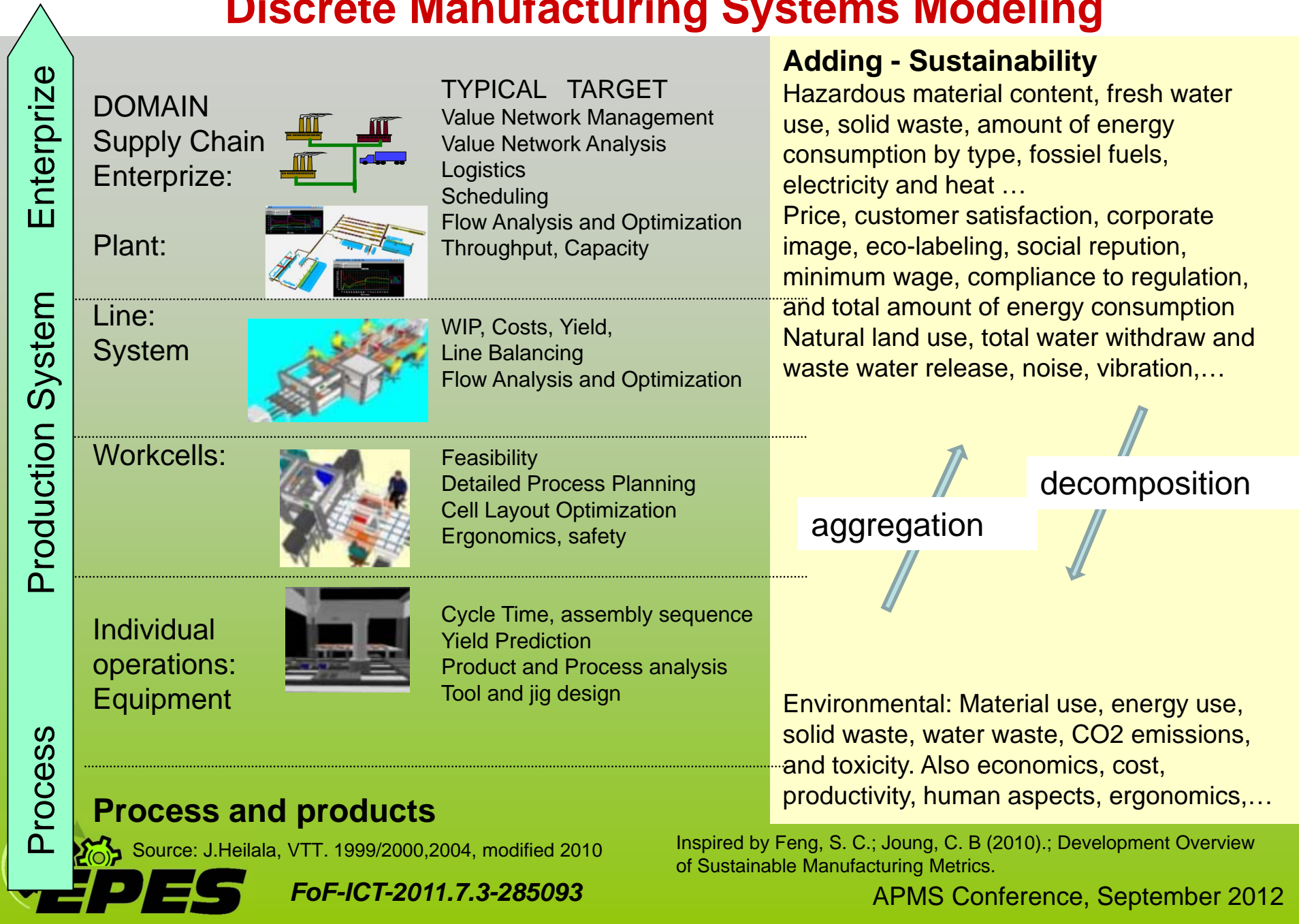
EADS: Aircraft manufacturer.
Assessment on productivity and sustainability KPIs on wing design concepts



Sustainability intelligence

- As sustainability related issues are becoming increasingly important in business decision making. Simulation & modelling are needed to analyse the system performance not only using traditional performance measures such as productivity and efficiency, but also taking into account sustainability related performance measures.
 - Our solution: Adding transparency to the decision making process with sustainability aspects in manufacturing simulation & Simulation as a Service for non simulation-experts.
 - “Automation of eco-design engineering process in specific domain”
-

Discrete Manufacturing Systems Modeling



Source: J.Heilala, VTT. 1999/2000,2004, modified 2010

Inspired by Feng, S. C.; Jung, C. B (2010).; Development Overview of Sustainable Manufacturing Metrics.



FoF-ICT-2011.7.3-285093

APMS Conference, September 2012

Challenges for sustainable manufacturing system simulation

- Challenges for simulation of sustainable manufacturing, such as the lack of:
 - Source of the sustainability information, sustainability metrics and indicators
 - A reference model to identify appropriate information
 - Information models that support simulation for sustainable manufacturing
 - Modelling methods for simulation of sustainable manufacturing
 - Measures to evaluate sustainability.

Source of information

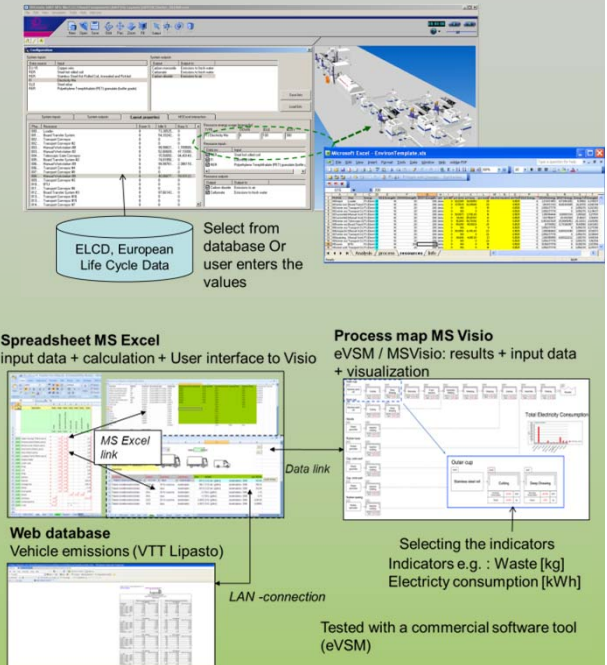
- Indicators and metrics:
 - Sustainable manufacturing indicators [OECD 2011]
 - Environmental metrics [EPA]
 - 37 key environmental indicators of the 2009 Environment Policy Review [EC 2009]
 - Corporate Communication Global Reporting Initiative [GRI 2001].
 - Sustainable manufacturing Indicator Repository [NIST 2010]
- LCI data
 - Open database, eg. ELCD, European Life Cycle Data, (<http://lca.jrc.ec.europa.eu/lcainfohub/datasetArea.vm>)
 - LCA tools databases (IPR issues)
- Standardisation
- State of the Art, Journals and Conferences e.g. APMS

How to model

- Manufacturing simulation with sustainability aspects, one of the first steps is to **define the scope** of study and **select suitable indicators** for assessment.
 - Manufacturing simulation is event based process oriented study focused on **material flow, and resources**, equipment and human operators.
 - For **sustainability issues** we are adding **energy flow** study, (energy consumption), more detailed **consumables study**; e.g. materials, (dimensions, type), components, semi products, lubricants, chemicals, waste generation, and also **emission study** (air emission, aerosol particle, water emission).
-

Few examples: manufacturing sustainability and energy efficiency evaluation

- Use of discrete event simulation (DES)
 - Multiple examples documented, can be done with different tools
 - Even commercial software have presented solution (limited features)
- Use of Value stream mapping (VSM)
 - Training material exist (EPA, USA)
 - Low entry level, paper and pencil, or use of software
- Use of Life Cycle Assessment (LCA) tools
 - Typically robust, simplified, screening
- Common problem, getting high quality data



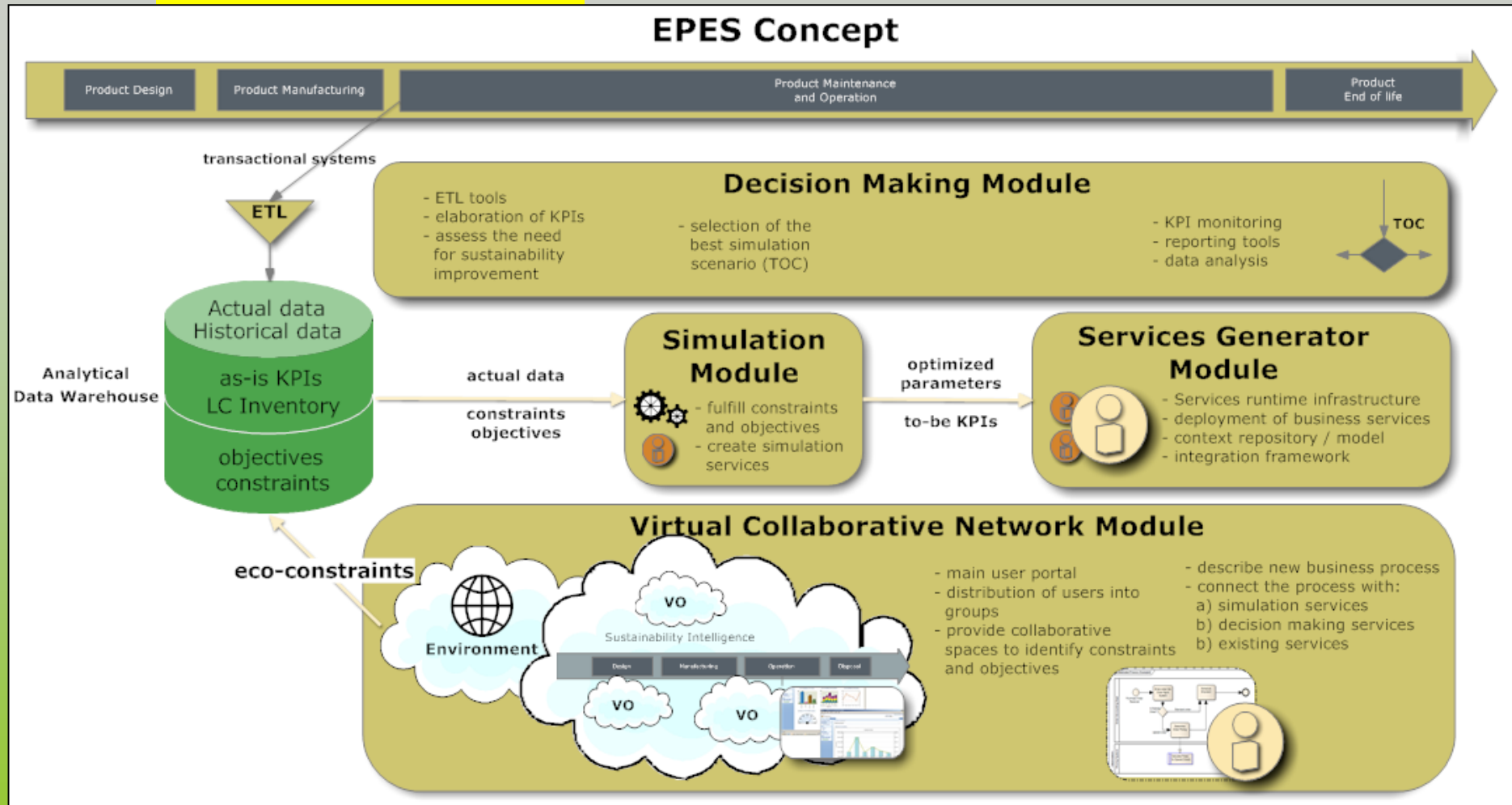
Development of process-oriented environmental modules

- The **general methodology** for developing the process-oriented, **environmental modules of the sustainability simulation** toolkit
 1. **Identify** sustainability factors and environmental performance measures for systems of interest;
 2. Establish **simulation state variables** to represent the sustainability factors and performance measures;
 3. Identify the **events** in the system that cause changes to the state variables, and translate these system events to simulation events and the associated event triggers;
 4. Establish the mathematical, statistical, and logical **relationships** among the state variables to update and change the values of the state variables as events occur in the system over time;
 5. Implement state variables, relationships, and events into a robust, flexible simulation toolkit modules; and
 6. Perform verification, **validation**, and testing of the simulation toolkit modules.

Based on . Xi Zhou. Michael E. Kuhl. (2010). DESIGN AND DEVELOPMENT OF A SUSTAINABILITY TOOLKIT FOR SIMULATION. WSC 2010



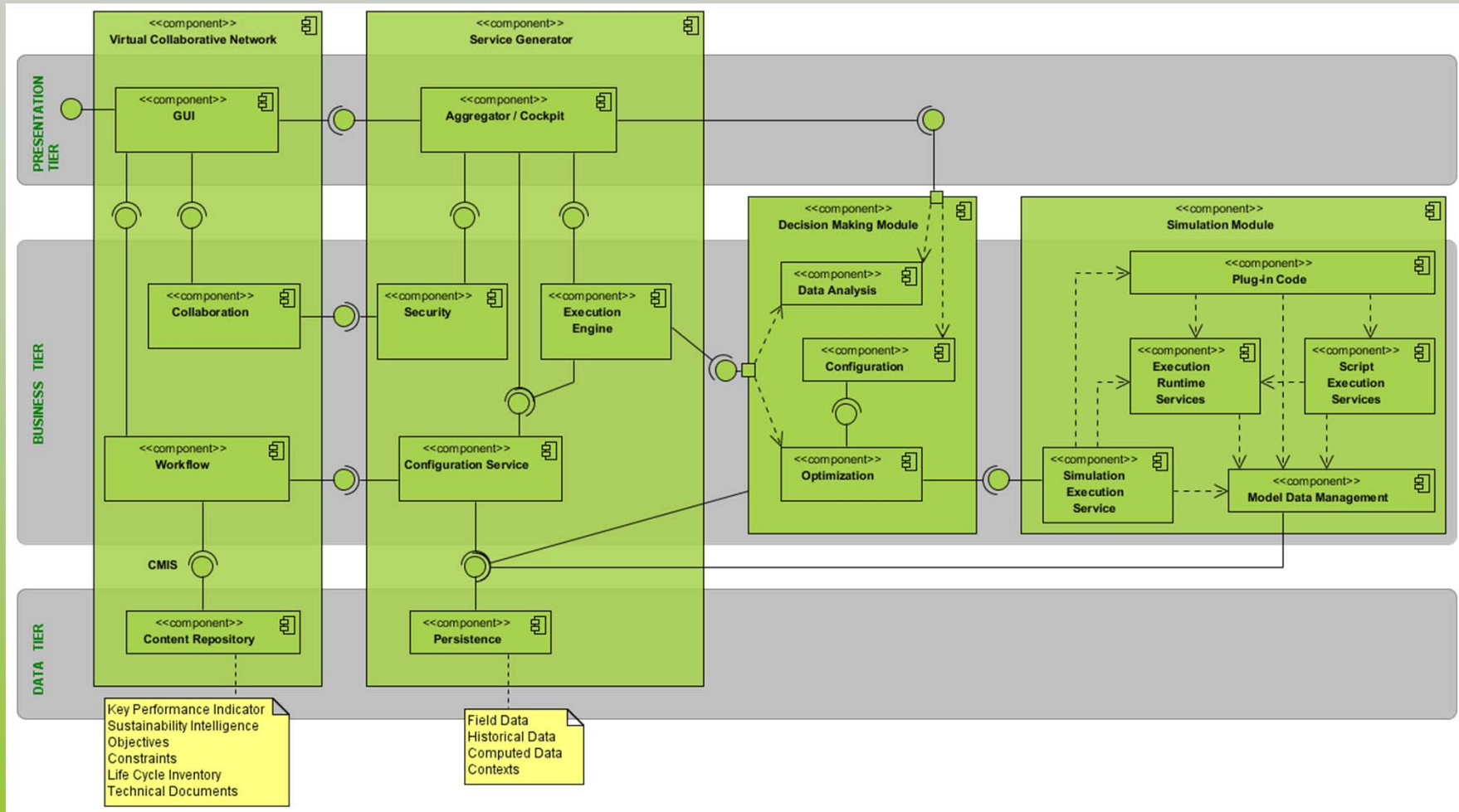
EPES system (concept)



FROM D100.3 EPES Concept

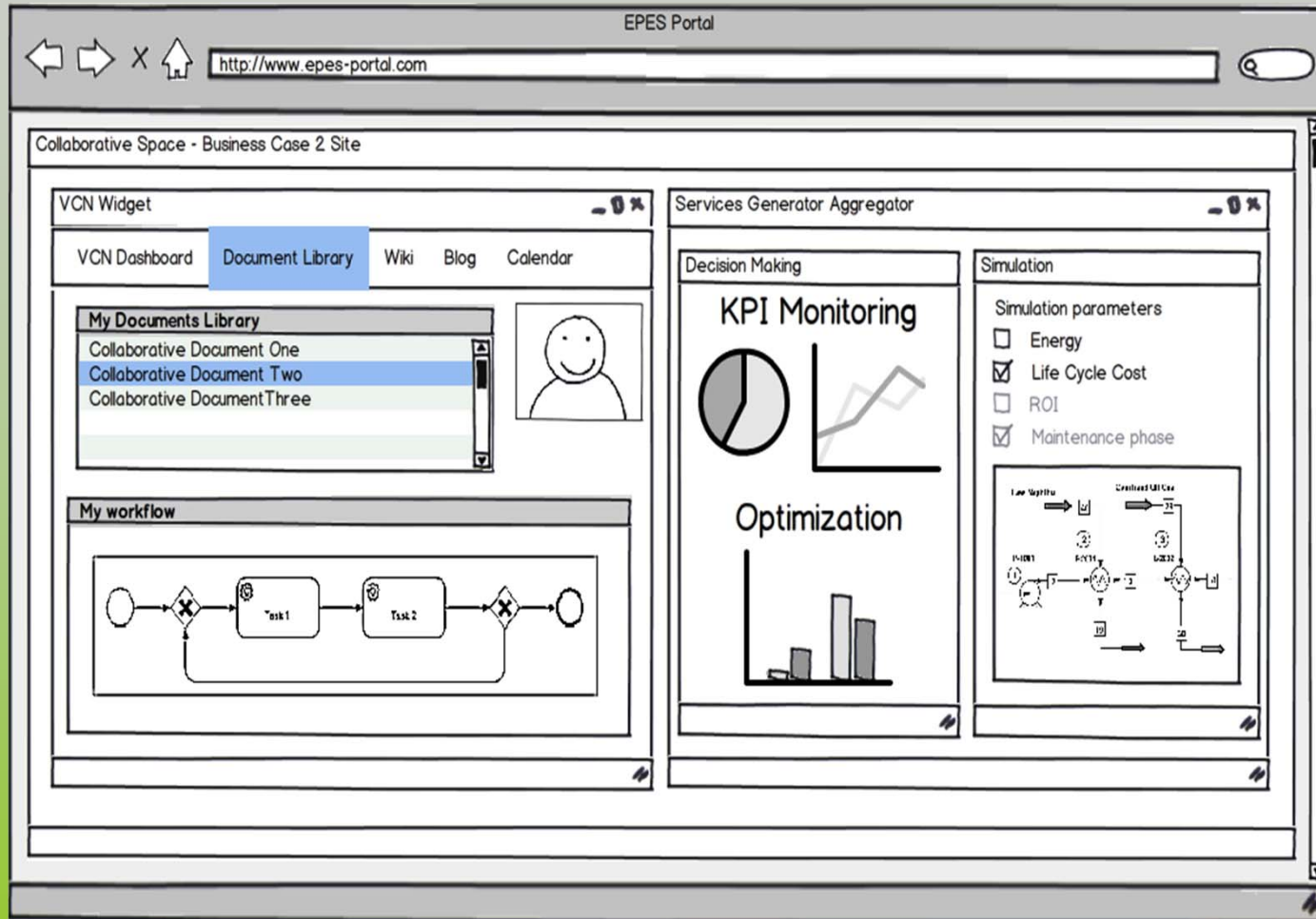


EPES Early Prototype Architecture



FROM D100.3 EPES Concept

VCN graphical user interface mock-up



Simulation:

- Black box simulation on web
- Data driven automatic model re-configuration
- Domain specific, not yet universal

EPES demonstration wing design concept - BC3

- The end users will be “**design for manufacturing**” engineers, doing the assessment of design concepts.
 - Support to make informed decisions on the performance of design concepts from the manufacturing and sustainability perspective.
 - Integrate the assessment of **manufacturing Key Performance Indicators** (KPIs) such as time and production rate with those related to the **sustainability of the production processes**.
 - The essential questions answered through this assessment are:
 1. **Productivity KPIs**: What **production rate** can be achieved for a design using a given **set of processes and resources**?
 2. **Sustainability KPIs**: What are the **energy consumption, the emissions** and the hazardous material waste resulting from the manufacturing for a design using a given set of processes and resources?
-

Simulation workflow

VCN , Access "Portal" to EPES system, collaboration environment, workflow, data repository, CMS, Content Management System

SGM, Aggregator/cockpit, service generator/configuration, execution

Select simulation tool and template model

Define simulation input data and parameters



Seed model & List of processes, tools, resources and their parameters

DMM, Data visualisation

DoE, Design of Experiments

Visualisation and result analysis

Multi-Objective Optimisation

SM, Simulation execution

Simulation model and data management

Simulation execution

Potential post processing

Simulation model data management

Inputs:

- list of processes, related tools and resources and their parameters, e.g. cycle time, space requirements, **process chemicals**
- resource data, **energy consumption model, busy, idle, down or more detailed model and energy carrier for emission calculation**
- product and **material data, to identify hazardous materials**
- cost parameters
- factory calendar and working shifts 1, 2, 3 or 24/7
- Orders

Outputs;

- production key performance indicators; utilisation, production capacity, lead time, bottlenecks, floor space needed, cost analysis
- **energy consumption, related CO2 emission, hazardous waste,**

Summary

- This is on-going work, now we have EPES laboratory prototype, Early Prototype in February 2013, Full Prototype in August 2013
- Instead of large static, spread sheet models => **dynamic and integrated modelling**
- Instead of desktop application, engineering islands of analysis => **integration of assessment methods and provide them as a service for non-simulation experts (but domain specific)**
- New supporting services for assessment of productivity and sustainability KPIs on early product design => **conceptual stage DFMA and sustainability assessment.**
 - Validation of production scenarios on early stages considering dynamic conditions.
 - Improved decision making for an optimum manufacturing facility will be supported.

THANK YOU

Q&A





EPES Consortium



Countries (IT, ES, DE, UK, FI)
RTDs (VTT, ATB, TEC)
End-Users (TAM, NKT, EADS)
SW Vendors (SIST, EST)

➤ Coordination: Mikel Sorli, tecnalia