



Data-driven Simulation of the Extended Enterprise

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Simulation of the Extended Enterprise

- **Supply chain design is a key focus of modern manufacturing in the Extended Enterprise (EE)**
- **With the ever increasing complexity and dynamics of supply chains, simulation is a powerful tool to assess EE performance**
- **In traditional simulation approaches, the model is constructed by a user, who defines a model step-by-step using the user interface of the simulation tool**
- **If model configuration must be changed, this must be carried out by a simulation expert, thus greatly limiting the usefulness of simulation to non-expert users**



Data Driven EE Simulation

- **The concept of data-driven modelling and simulation of the supply chain/EE has been adopted.**
- **Enabled by the relatively limited domain nature of a supply chain/EE**
- **The model is constructed automatically by a the Supply Chain Model Builder application, based on data existing in company IT systems**
- **Model development time is greatly reduced**
- **A model created this way can be reconfigured rapidly, by changing the external data.**
- **User can explore the implications of radical changes to a simulated EE, with little knowledge of the simulation software itself**



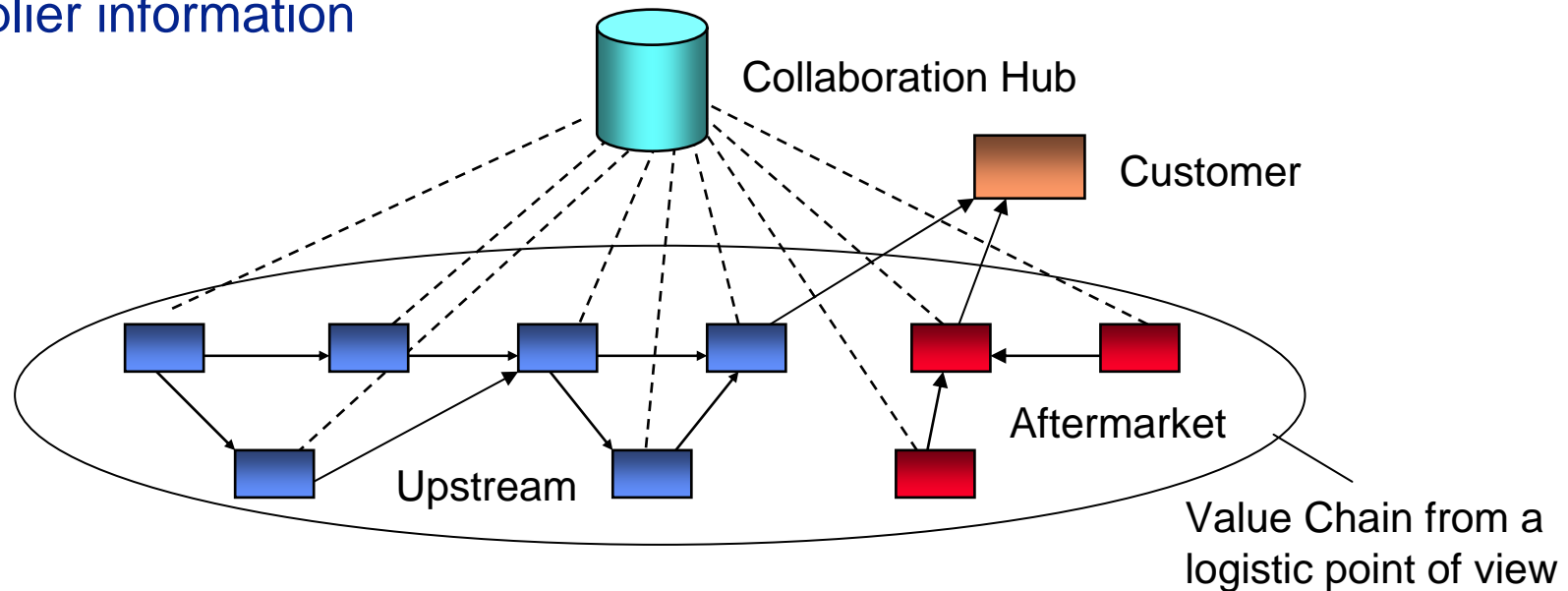
Aerospace Engine Industry Supply Chain

- Some characteristics of the aerospace engine industry:
 - Complexity of the product/service offering (inc. bundled service and build kits, etc.)
 - Importance of aftermarket supply chain (inc. MRO, component repair, etc.)
 - Global nature of supply chain, increasing importance of Far East (esp. China, Japan, etc)
 - Suppliers often chosen for high-level business reasons (e.g. R&R sharing) with little consideration of logistics issues
 - Component value and therefore high cost of holding inventories
 - Complex relationships between businesses that can operate at several levels in the supply network



The VIVACE Extended Enterprise Concept

- Partners in the aerospace Extended Enterprise are connected via a collaboration hub
- Each enterprise partner provides information about its capabilities to the collaboration hub
- Supply Chain simulation techniques can access the hub to obtain supplier information





Data Driven Modelling of the EE

- In VIVACE, a data-driven simulation would mean that a database of supplier information (ultimately in the Extended Enterprise Collaboration Hub) would be interrogated, and a corresponding set of nodes created within a network model, each node with appropriate properties representing the relevant capabilities of the supplier which it represents
- The network model can then be transferred to discrete-event simulation system to explore its performance and dynamics
- At present, the VIVACE Collaboration Hub is not yet available and the system uses information from SAP, such as extended BoM data for model creation

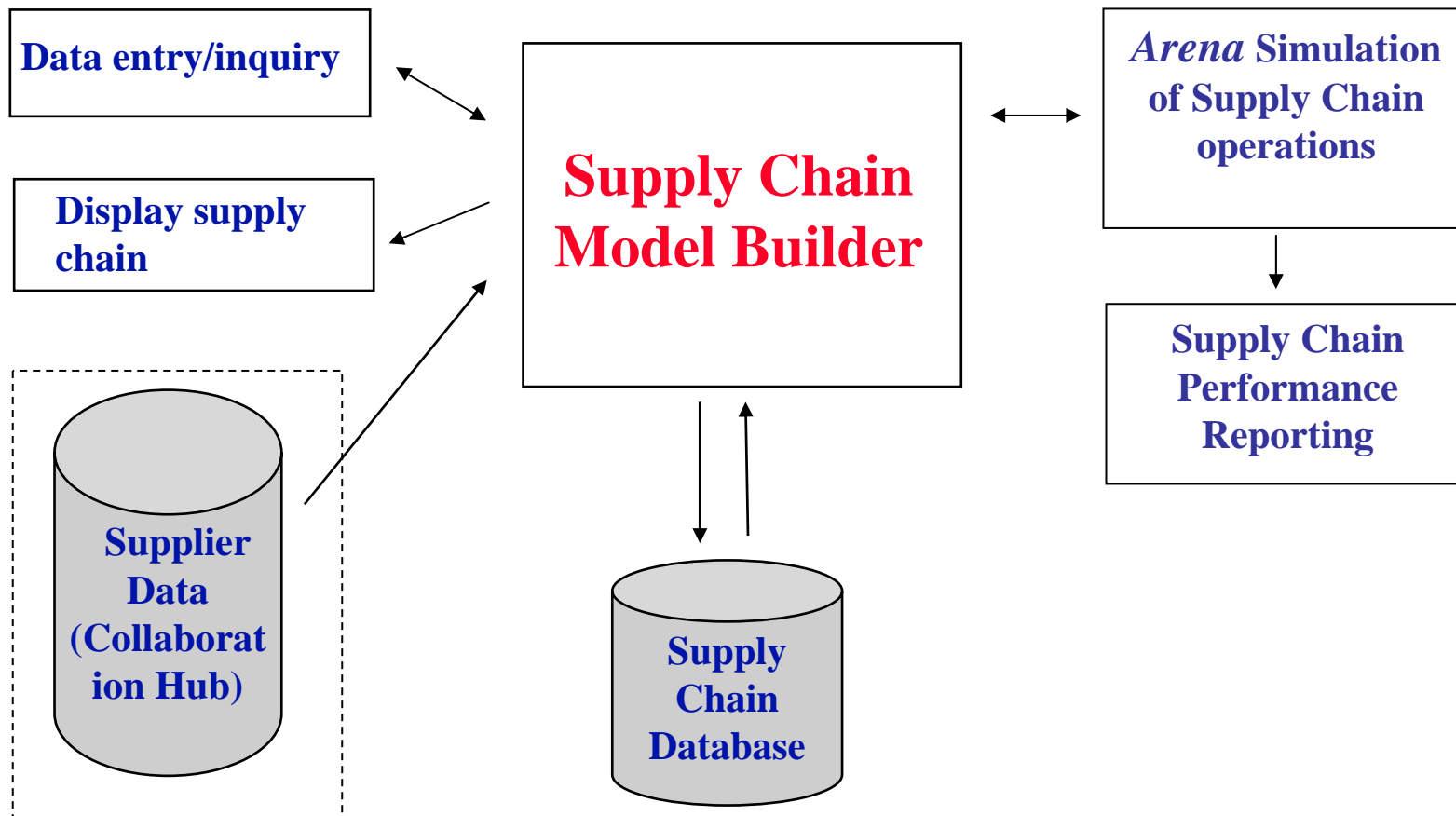


Why Data-driven Simulation in Vivace?

- Evaluating supply chain implications for different extended enterprise and supplier options
- ‘What-if’ questions to understand complex supply chain behaviour, e.g.
- Up-front evidence Demand variability and other uncertainties
 - Information distortion
 - Evaluating supply chain implications for new product designs
 - of logistics issues associated with suppliers
- Assistance with the ‘7-day proposal’ (WP 2.1) for new products



Data-driven Modelling/Simulation Architecture





Screenshot of the Supply Chain Model Builder

Supply chain - [The whole supply chain - All the possible supply chains]

File Data Entry Data Enquiry Report Tool Window Help

Treeview:

- The whole supply chain
 - TR800(Trent 800 Engine)
 - HPS_T800(High Pressure System_T800)
 - RR(Rolls Royce)
 - DoAss_T800(Disc Assembly_T800)
 - MTU(MTU)
 - HP_Comp_T800(HP Compressor_T800)
 - ITP(Industrio de Turbo Propulsores)
 - HP_TBN_T800(HP Turbine_T800)
 - VAC(Volvo Aero Corporation)
 - HPCmPCs_T800(HP Compressor Casing_T800)
 - BEAUFORT(Beaufort Engineering)
 - HPS_InCs_T800(HPS Inner Casing_T800)
 - BEAUFORT(Beaufort Engineering)
 - HSG_T800(High-Speed Gearbox_T800)
 - RR(Rolls Royce)
 - HP_TBN_T800(HP Turbine_T800)
 - VAC(Volvo Aero Corporation)
 - IP_TBN_T800(IP Turbine_T800)
 - VAC(Volvo Aero Corporation)
 - LP_TBN_T800(LP Turbine_T800)
 - MTU(MTU)
 - IPS_T800(Intermediate Pressure System_T800)
 - RR(Rolls Royce)
 - IPC_T800(Intermediate Pressure Compressor_T800)
 - ITP(Industrio de Turbo Propulsores)
 - IPT_T800(Intermediate Pressure Turbine_T800)
 - VAC(Volvo Aero Corporation)
 - ITC_T800(Intermediate Case_T800)
 - BEAUFORT(Beaufort Engineering)
 - LPS_T800(Low Pressure System_T800)
 - RR(Rolls Royce)
 - LPCC_T800(Low Pressure Compressor Case_T800)
 - BEAUFORT(Beaufort Engineering)
 - LP_Comp_T800(LP Compressor_T800)
 - LPC_fCsg_T800(LP Compressor Front Case_T800)
 - LPC_rCsg_T800(LP Compressor Rear Case_T800)
 - LPCR_T800(Low Pressure Compressor Rotor_T800)
 - LPT_T800(Low Pressure Turbine_T800)

Product supply chain structure of a product TR800(Trent 800 Engine)

| Subitem Code | Product Name | Type | Qty | Comp. | Vol. | Sc |
|--------------|-----------------------------------|------|-----|-------|------|----|
| HPS_T800 | High Pressure System_T800 | 2 | 1 | True | True | I |
| HSG_T800 | High-Speed Gearbox_T800 | 2 | 1 | True | True | I |
| IPS_T800 | Intermediate Pressure System_T800 | 2 | 1 | True | True | I |
| LPS_T800 | Low Pressure System_T800 | 2 | 1 | True | True | I |

Suppliers' performance on subitems of a product TR800(Trent 800 Engine)

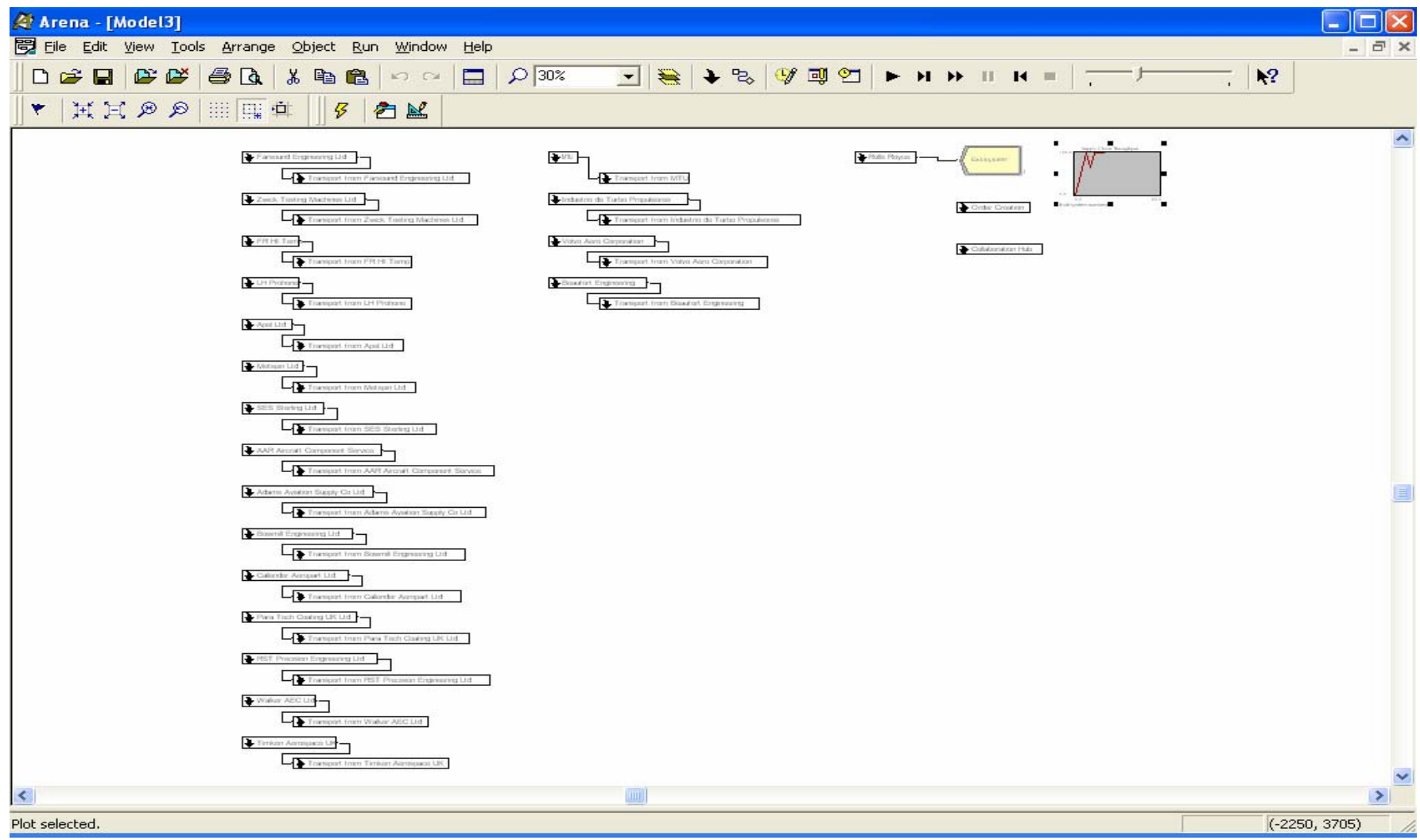
| Subitem Code | Product Name | Type | Supplied By | Supplier Name |
|--------------|-----------------------------------|------|-------------|---------------|
| HPS_T800 | High Pressure System_T800 | 2 | RR | Rolls Royce |
| HSG_T800 | High-Speed Gearbox_T800 | 2 | RR | Rolls Royce |
| IPS_T800 | Intermediate Pressure System_T800 | 2 | RR | Rolls Royce |
| LPS_T800 | Low Pressure System_T800 | 2 | RR | Rolls Royce |

N.B. Dummy Data

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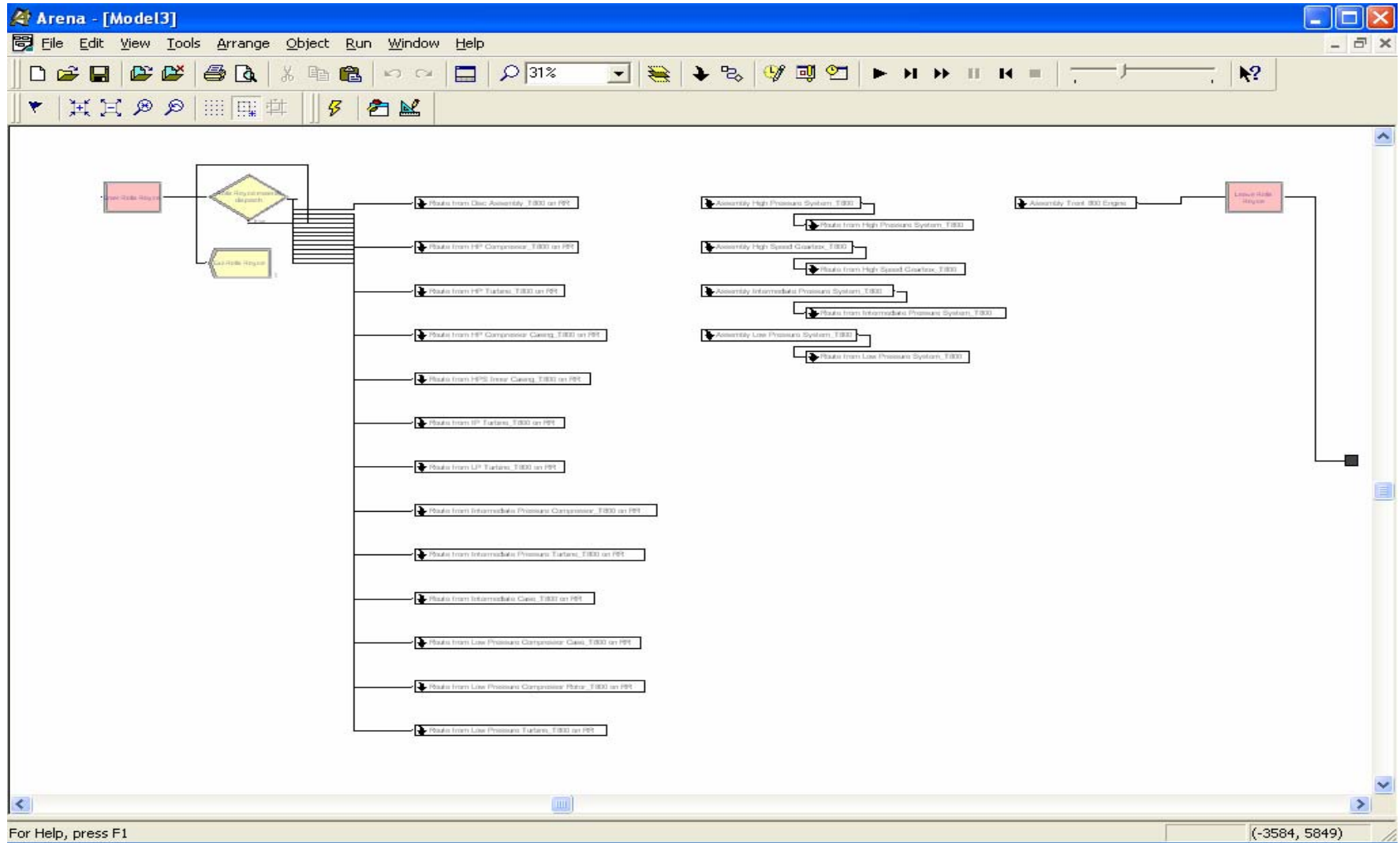


The Top Level Model of Data-driven Supply Chain in Arena



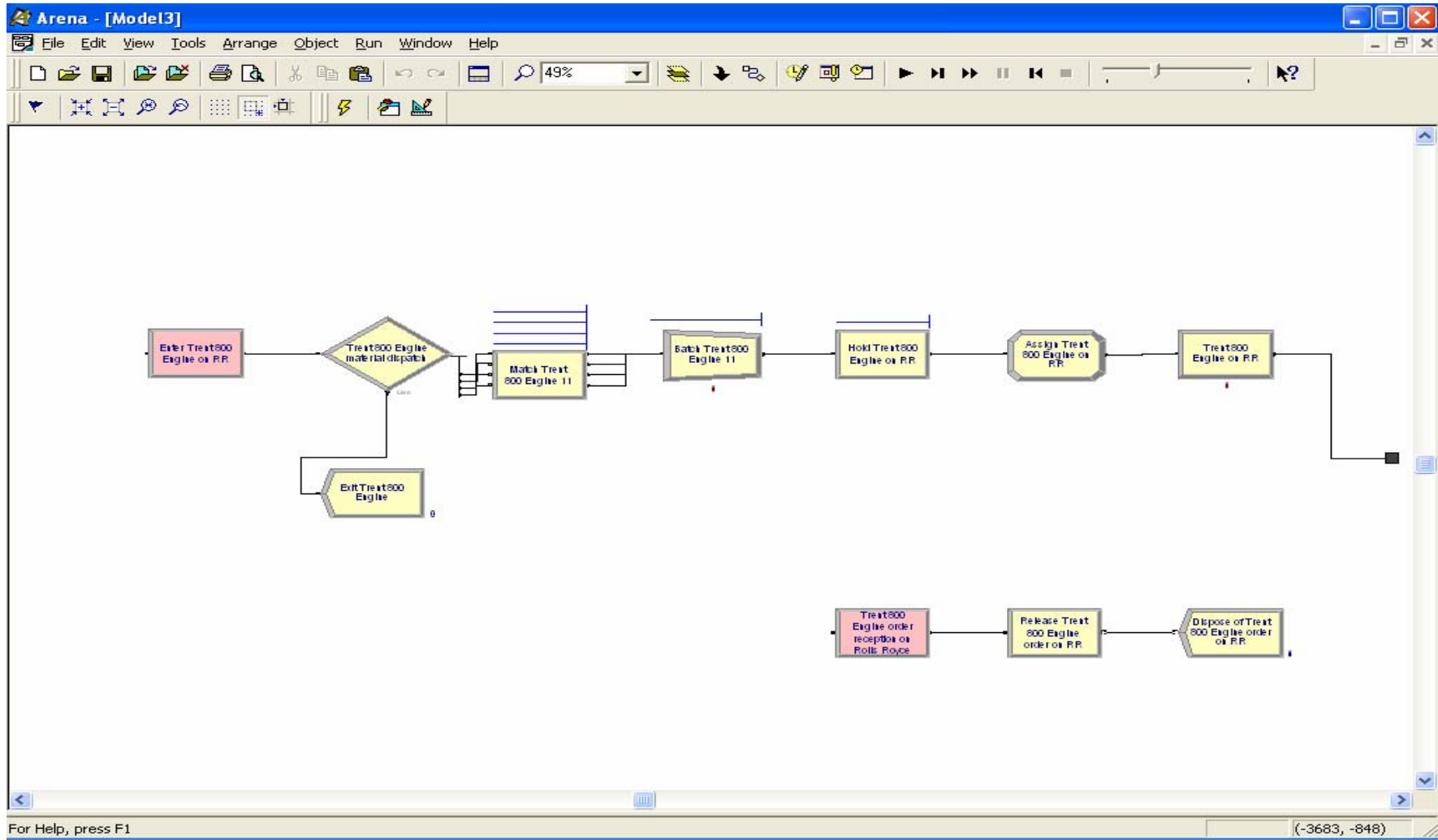


A Supplier Sub-model



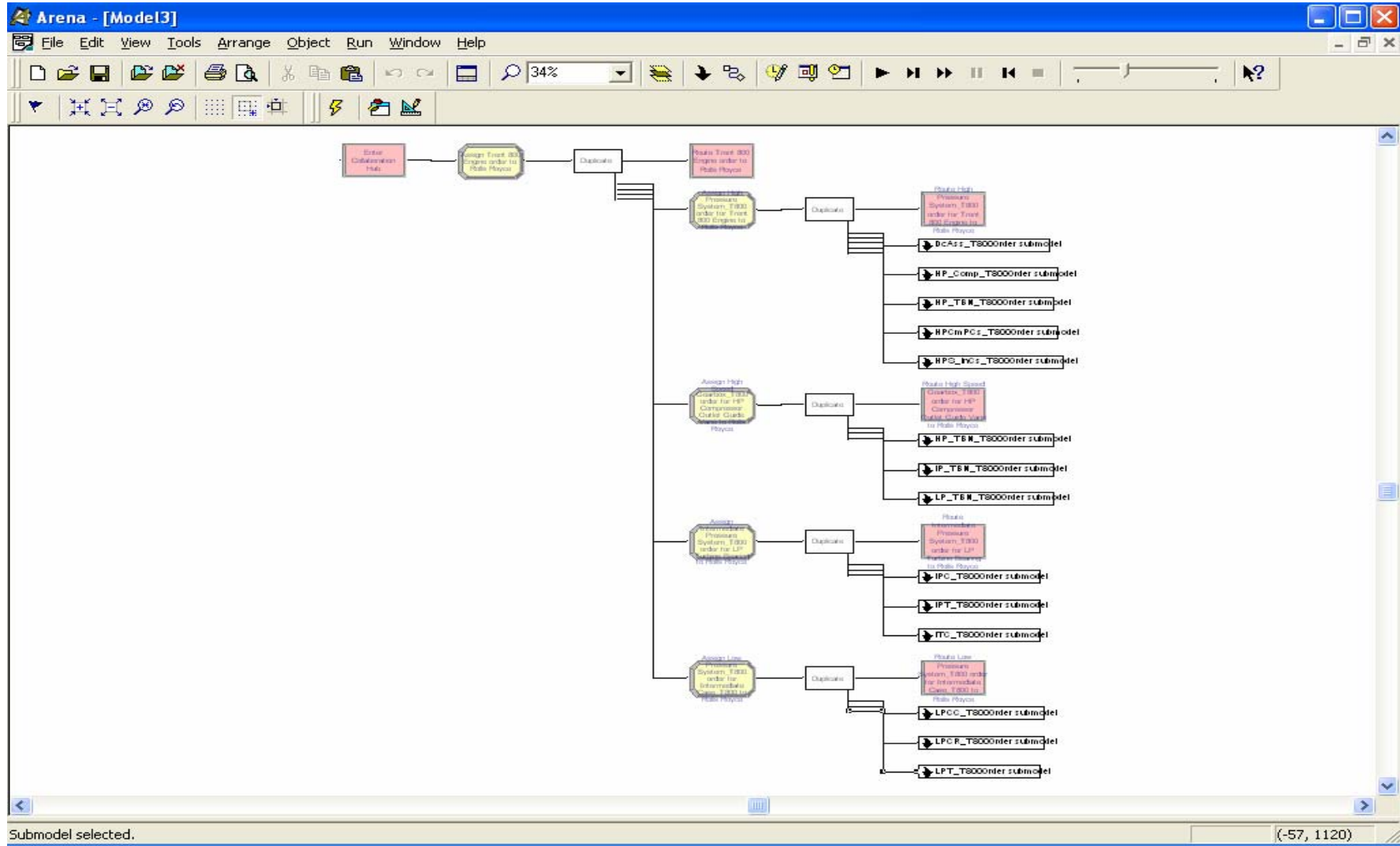


An Assembly Sub-model





The Collaboration-hub Ordering Model





Supply Chain Performance Measurement

- Performance on the aggregated level
 - Calculate a single weighted and normalized multi-criterion metric, based on
 - performance metric categories, individual metrics, weightings, simulated metric values, weighted and normalized values for categories, absolute benchmarks, relative benchmarks
- Performance on the detailed level
 - The key performance indicators (KPI), e.g. delivery lead-time, WIP costs and manufacturing reliability, can be plotted on two-dimensional graphs

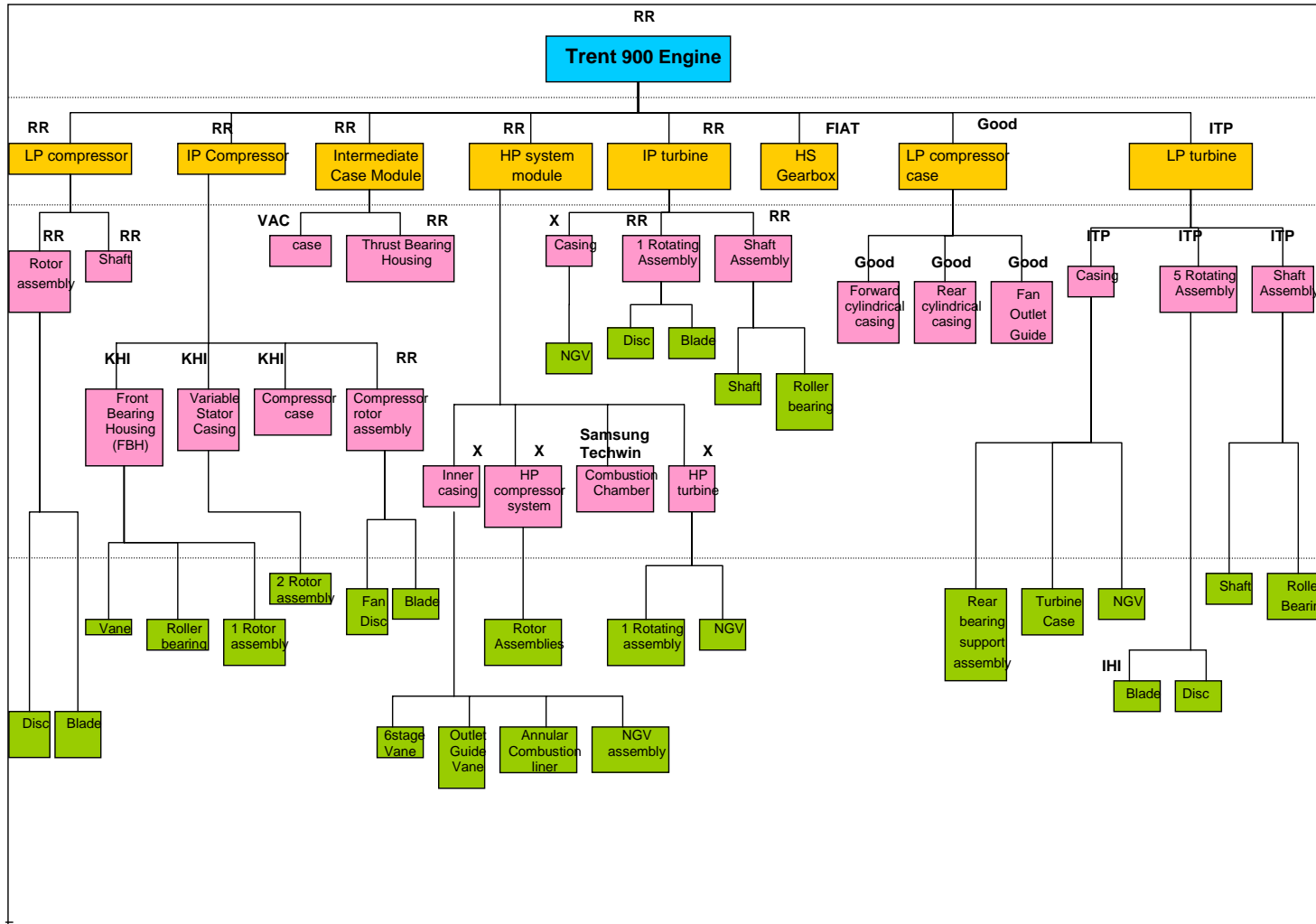


Status of DD Model Creation

- Methodology: starting from the main supplier the model is built 'backwards' down to the lowest level suppliers
- Model structure: a multi-layer structure potentially allowing for modelling realistic supply chains, e.g. any selection of supplier, product, network structure
- Model creation: an Arena model is automatically created from the database, using a Visual Basic application, the Supply Chain Model Builder (SCMB)
- The model currently runs with dummy data based on a Trent 800 BoM, using three-levels of supplier

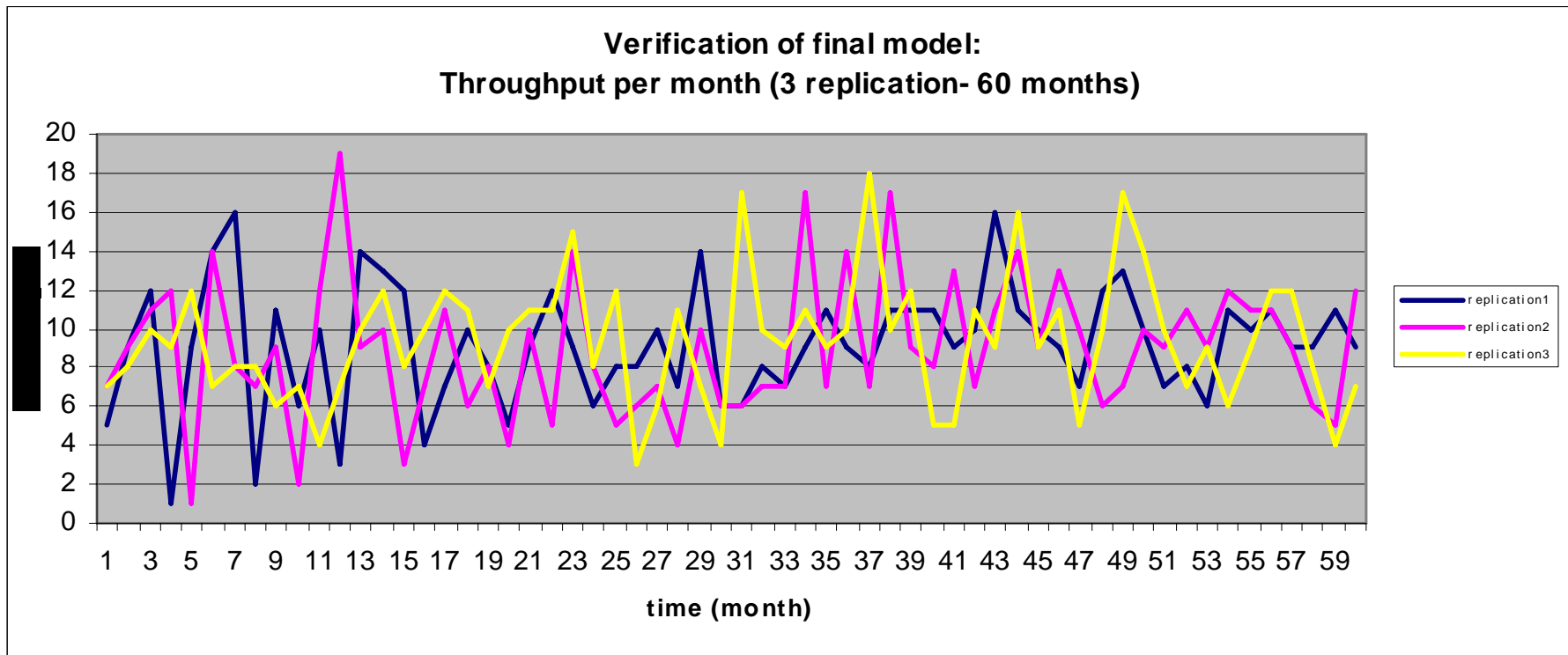


RR Trent 900 BOM



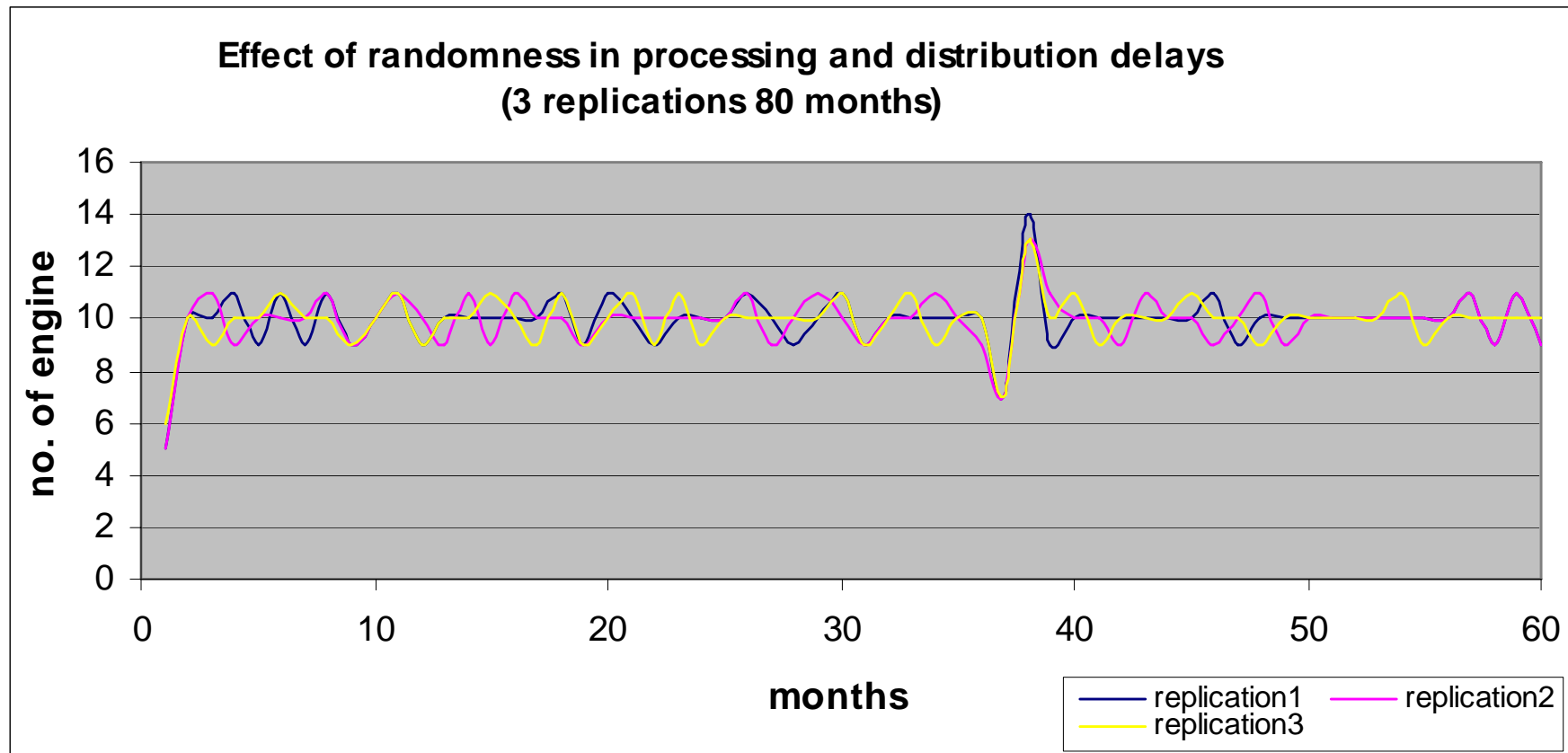


Trent 900 throughput rate





Effect of Randomness in material supply





Future Developments

- Further improve the prototype model for better efficiency and functionality. Adding
 - information flow and control
 - animation
 - reporting
- Model verification and testing programme
- Use case developments, requiring additional realistic supplier and logistics information (e.g. Trent 900) from industrial partners
- Experimenting with model and simulation settings, e.g. deciding steady-state requirements
- Validation and Experimentation with use cases
- Modifying the database and model to accommodate new functionality as required by users