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Enterprise Engineering with CIMOSA - Application at FIAT

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Abstract

CIMOSA will support the increased need for real time and up-to-date information through identification of available information and its use in the operational processes of the manufacturing enterprise. Process based enterprise modelling also allows to describe the operational dynamics as well as resources needed and related organisational aspects. Such models may be used in decision support designing and evaluating operation alternatives through simulation. Experiences from model engineering obtained in applying CIMOSA in FIAT manufacturing are reported in the second part of the paper. The business as well as engineering value of CIMOSA has been identified in terms of significant reduced model engineering time, very much increased modelling flexibility and much more meaningful analytical capability.

Keywords

Open System Architecture, CIMOSA, CIMOSA Application, Enterprise Integration, Enterprise Modelling. Simulation

P. Ladet et al. (eds.), *Integrated Manufacturing Systems Engineering*

PART I: CIMOSA ENTERPRISE ENGINEERING

1 INTRODUCTION

The manufacturing industry is deeply in the paradigm shift from manufacturing of scale and manufacturing automation to flexible manufacturing and management of change. This shift brings about an increasing need for up-to-date information, available at the right place, in the right time, with the right amount and the right format. This in turn requires improved orientation in the ocean of information which is available in any sizeable manufacturing enterprise. Information which is created at many different places during the product life cycle and which is needed in many more places to allow efficient continuation and completion of the business processes.

The most effective way to identify the needed information and obtain access to it is via models of the enterprise operation which cover not only its business processes but identify both their internal and external relations as well. However, to achieve sufficient flexibility for maintaining the models and keeping them really up-to-date modelling has to become a tool not only for planning but for operational support as well. For this goal model engineering has to be based on industry standards providing for industry-wide understandability and even more important interchangeability.

The ESPRIT Consortium AMICE[1] has developed, validated, verified and introduced into industry as well as standardisation the CIMOSA (Open System Architecture for CIM) concept of enterprise engineering and model driven enterprise operation control and monitoring (ESPRIT Consortium AMICE, 1993). A concept which has been evaluated and validated by other ESPRIT projects (CIMPRES, CODE, VOICE), professional societies (IFIP/IFAC, others), independent organisations in many countries (China, France, Germany, Hungary, Japan, Switzerland, others) and last but not least by AMICE member organisations. National, European and international standardisation bodies (CEN, ISO) have started normative work to establish standards based on these concepts (CEN, 1990).

CIMOSA is an ESPRIT[2] supported pre-normative development aimed on process based enterprise modelling and application of these models in model driven enterprise operation control and monitoring. Process based enterprise models are an excellent means to structure and identify the information created and used during the production processes and thereby make it available from any place in the enterprise at any time with the amount and in the format needed during a particular process step. CIMOSA consists of an Enterprise Modelling Framework and an Integrating Infrastructure.

2 CIMOSA MODELLING FRAMEWORK

CIMOSA is an ESPRIT supported pre-normative development aimed on process based enterprise modelling and application of these models in model based operation control and monitoring. Process based enterprise models are an excellent means to structure and identify the information created and used during the production processes and thereby make it available from any place at any time with the amount and in the format needed at a particular process

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1 European CIM Architecture - in reverse.
2 European Strategic Programme for Research and Development in Information Technology.

step. Such models may be used in decision support for engineering operation alternatives and evaluating those through simulation.

The modelling framework shown in Figure I.1 structures the CIMOSA Reference Architecture into a generic and a partial modelling level each one supporting different views on the particular enterprise model. This concept of views allows to work with a subset of the model rather than with the complete model providing especially the business user with a reduced complexity for his particular area of concern. CIMOSA has defined four different modelling views (Function, Information, Resource and Organisation). However this set of views may be extended if needed.

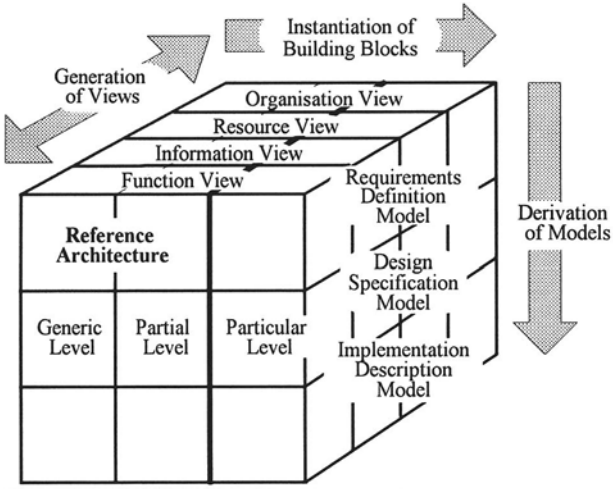

Figure I.1 CIMOSA Modelling Framework.

The CIMOSA Reference Architecture supports modelling of the complete life cycle of enterprise operations (Requirements Definition, System Specification and Implementation Description). Again the sequence of modelling is optional. Modelling may start at any of the life cycle phases and may be iterative as well. Depending on the intention of model engineering only some of the life cycle phases may be covered.

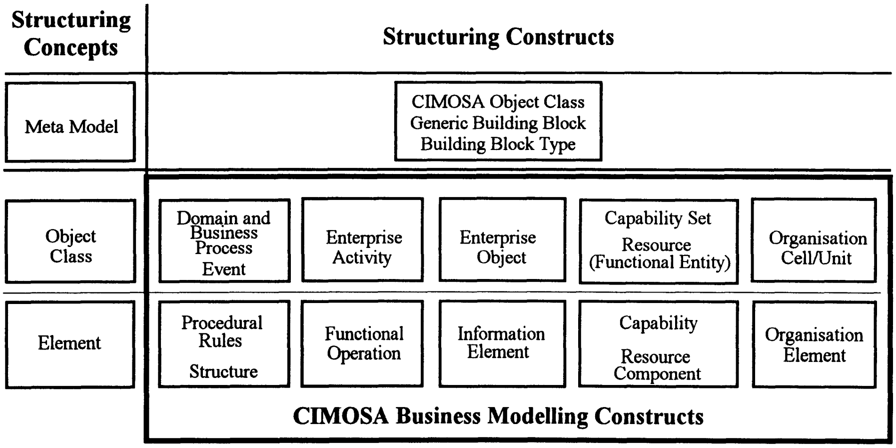

Figure I.2 CIMOSA Constructs.

Enterprise operation should not be modelled as a large monolithic model but rather as a set of co-operating processes. With a set of common modelling building blocks, the CIMOSA Reference Architecture provides the base for evolutionary enterprise modelling. This allows different people to model different areas of the enterprise but provides the integrity of the overall model. Figure I.2 shows the basic set of the common building blocks for business modelling. Processes, Events and Enterprise Activities are the object classes which describe functionality and behaviour (dynamics) of the enterprise operation. Inputs and outputs of Enterprise Activities define the information (Enterprise Object) and resources needed. Organisational aspects are defined in terms of responsibilities and authorisation (Organisation Elements) for functionalities, information, resources and organisation and are structured in Organisational Units or Cells. CIMOSA employs the object oriented concepts of inheritance, structuring its constructs in recursive sets of object classes.

3 CIMOSA - PROCESS-BASED ENTERPRISE MODELLING

CIMOSA model engineering is demonstrated in Figure I.3 which shows three enterprise Domains (DM1-3) each one represented by its functionality - a set of Domain Processes (Domain Processes). Domain Processes communicate with each other via Events and Results. Decomposition of Domains Processes (DP2.1) via Business Processes (Business Processes) leads to identification of Enterprise Activities (EA1-5) and their connecting control flow represented by a set of Procedural Rules (PRS). The network of these Enterprise Activities is the functional and dynamic representation of the Domain Process DP2.1. Events (1-2) and Results (a-b) which relate to Domain Process DP2.1 actual trigger EA1 and EA2 and are produced by EA3 and EA5 respectively. The different Inputs and Outputs identified for each Enterprise Activity are shown in Figure I.3 as well without identification of Resource and Control I/O's and any identification of organisational aspects (for those details please refer to CIMOSA references).

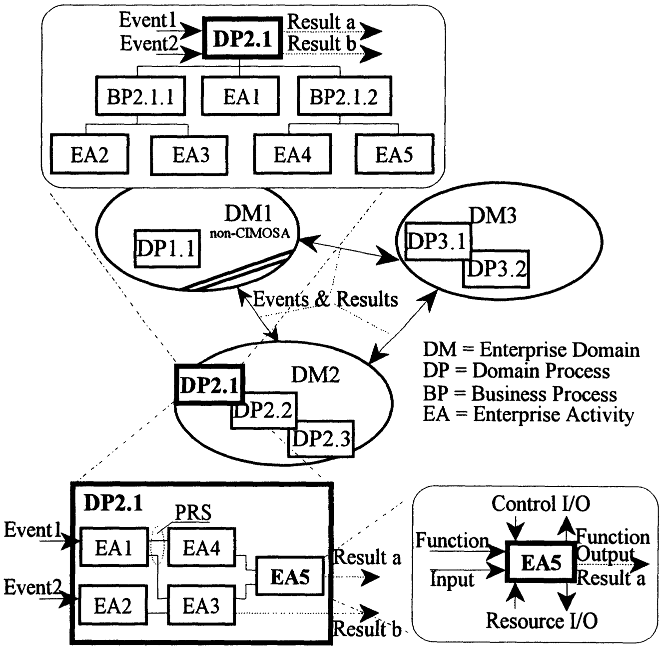

Figure I.3 Decomposition of Domain Process into Network of Enterprise Activities.

At system design level Enterprise Activities are further decomposed into Functional Operation (Figure I.4). Such CIMOSA Functional Operations are defined in relations to their executing resource types; the Functional Entities. Each Functional Operation will be completely executed by one Functional Entity, but a Functional Entity may be capable to execute more than one type of Functional Operation. Functional Entities are resources which are capable to receive, send, process and (optional) store information.

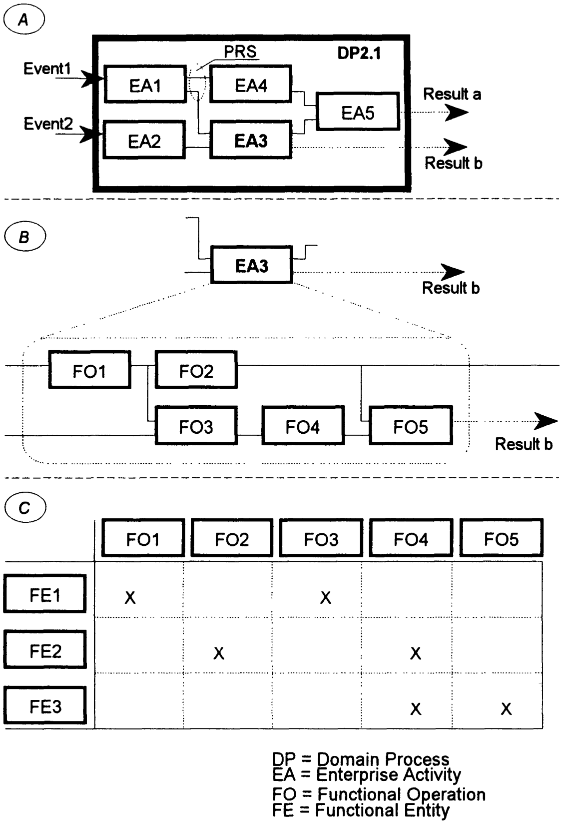

Figure I.4 Decomposition of Enterprise Activity and Relation between Functional Operations and Functional Entities.

4 CIMOSA INTEGRATING INFRASTRUCTURE

For model engineering and model driven enterprise operation control and monitoring especially in heterogeneous environments the Integrating Infrastructure provides a set of generic IT service entities for model engineering and execution (see Figure I.5 for the latter).

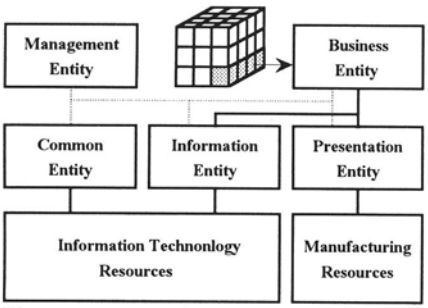

Figure I.5 Integrating Infrastructure.

Control on execution of the Implementation Description Model is provided by the Business Entity which receives the Events and creates occurrences of the related Domain process and all its contents. Process Control, Resource Management and Activity Control (all part of the Business Entity) analyse the model contents, assign the resources, identify the required information and connect to the necessary information technology and manufacturing resources via the Common, Information and Presentation Entities. Finally the Business Entity controls the execution of the Domain Process.

5 CIMOSA AND THE REAL WORLD

CIMOSA distinguishes explicitly between enterprise engineering and enterprise operation placing emphasis on the need for enterprise engineering in a similar mode of operation as for product engineering. Therefore the life cycle phases for enterprise engineering should be followed by an explicit release for operation processes including both model and implementation validation.

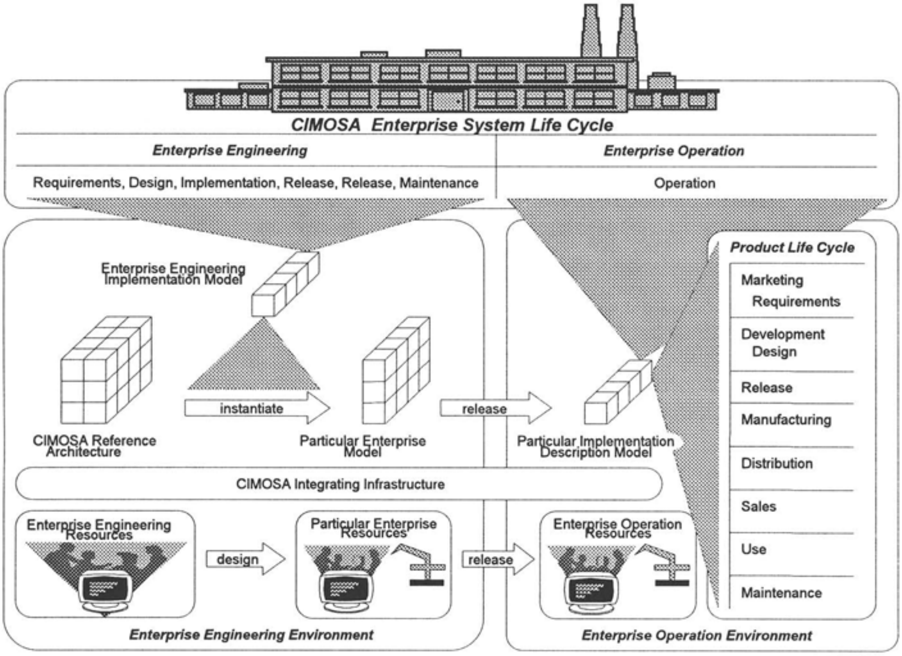

Figure I.6 CIMOSA concept and application.

Figure I.6 demonstrates the use of CIMOSA in model engineering as well as in operation control and monitoring. Using the CIMOSA Reference Architecture Particular Enterprise Models are engineered under control of the Enterprise Engineering Implementation Model. The latter will be implemented in a CAE tool guiding through the engineering phases of the CIMOSA System Life Cycle. The released Particular Implementation Model is then used to directly drive the operation through monitoring and controlling the relevant product life cycles or parts thereof and their business process implementations. The Integrating Infrastructure links to the enterprise resources. This link is required for model creation as well for real time model maintenance (model up-dates and extensions).

6 CIMOSA VALIDATIONS, APPLICATIONS AND EXPLOITATIONS

CIMOSA models provide for very high flexibility in enterprise engineering through fast modelling and evaluation via simulation of operation alternatives and direct implementation of the final solution. This has been explicitly verified by the AMICE project in the FIAT model engineering pilot implementation where CIMOSA has been used to model and evaluate operational alternatives in gearbox production and assembly. Compared with State of the Art methods currently applied by the FIAT Auto Division CIMOSA benefits are in considerable enhanced analysis capability (better structuring and more details on information, resources and organisation), much lower modelling time (reduced by factor of 3) and significantly improved re-usability of model parts (modelling time for similar application reduced by factor of 8).

The CIMOSA concept has been validated and verified in a total of 8 pilot implementation done by the ESPRIT projects AMICE, CIMPRES, CODE and VOICE covering both model engineering and model based operation control and monitoring. Results have been presented to the public in numerous publications and presentations (e.g. Petrie, C.J. Jr 1992)as well as demonstrations at several CIM Europe workshops. General descriptions of CIMOSA, user guides and technical specification have been made publicly available (CIMOSA Association 1994)and up-dates representing latest results will be presented to the public in the near future.

Exploitation of this work is done in both standardisation and product developments. Standardisation efforts on enterprise integration and based on CIMOSA results are currently in progress on ISO level (Framework for Enterprise Modelling), CEN level (Modelling Constructs/Building Blocks and Framework for Integrating Infrastructure) and various national organisations supporting international and European standardisation. Product developments especially on CIMOSA modelling tools have been reported by several IT vendor companies.

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PART II: CIMOSA ENTERPRISE ENGINEERING - APPLICATION AT FIAT

1 INTRODUCTION

FIAT has applied CIMOSA model engineering in a gearbox assembly plant analysis (see Figure II.1). This application includes the global modelling of the FIAT logistics processes for ordering parts and products (gearboxes) as well as the material flow control in the parts manufacturing-assembly-warehouse environment. Modelling the different processes in the Gearbox Manufacturing Domain has allowed to simulate different logistics scenarios and to analyse and evaluate the results in terms of throughput and turn-around time. Starting with Kanban and Push-Type production control, the optimum solution is a combination of both Push-Type in the purchasing and parts manufacturing areas and Pull Type in the gearbox assembly shop.

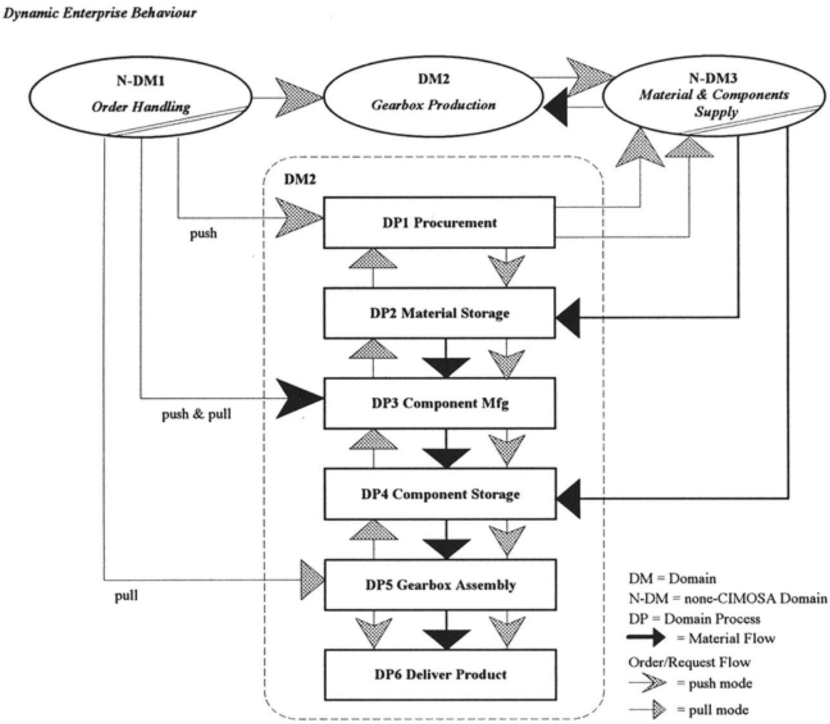


Figure II.1 FIAT Business Re-Engineering.

The CIMOSA Modelling Framework and Modelling Paradigms have been used to perform the modelling of this FIAT production system with the purpose of giving answers to the following three questions:

1) does CIMOSA improve the replies we get from modelling and simulation?
2) does CIMOSA improve the efficiency of the modelling process?
3) is CIMOSA implementable using existing technologies?

The following will demonstrate that three times yes are the answer to the above questions.

To understand the benefits which can be obtained by using CIMOSA it is necessary first to examine what is expected in the manufacturing environment from the processes modelling activities. As depicted in Figure II.2, today's strategy in design and manufacturing operations is to perform validation operations on the designed processes as early and as efficiently as possible.

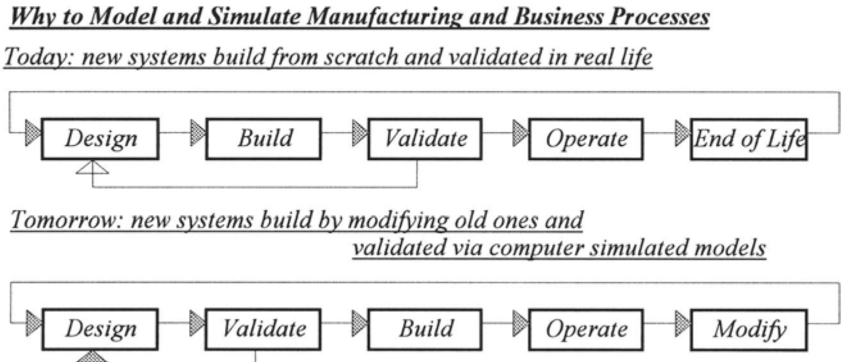


Figure II.2 Changes in the system design process.

2 VALIDATING CIMOSA AT FIAT

In the last years, FIAT, as well as other companies, has experienced the benefits of modelling and validating its manufacturing systems before building and operating them. The experience has shown the need of a structured and integrated approach to better organise modelling activities. Such need has been expressed in a set of requirements the models must fulfil. Depending on the purpose the models are used for, such requirements are the following:

Process Verification: design of enterprise processes requires frequent on-going verification steps. Models must describe the dynamic behaviour of the enterprise and must be capable to be verified by simulation.

Enterprise Process Integration: design of the enterprise involves many interacting processes:

- Production and Maintenance,
- Logistics,
- IT Systems,
- Suppliers,
- Personnel Management and Organisation,
- Marketing and
- Administration.

A good design is optimised over the interaction and the integration across these different processes. Models integrating the descriptions of the different processes of the enterprise are required to allow co-design and design optimisation.

Process Views Integration: Enterprise needs to be described in terms of:

- Performed Functions and their behaviour,
- Used Information,
- Employed Resources and
- Organisation.

Models must contain views on Functions (Processes), Information, Resource and Organisation. Such views must be structured, conceptually separated, comprehensive but physically integrated. Other requirements for industrial models are:

Modelling Efficiency: Models must maximise the ratio between the obtained benefits (accurate description of the enterprise, simulation capabilities, ...) and the efforts required to produce the models. Models must be built as much as possible by re-usable building blocks having different levels of complexity.

Coverage: The building blocks used for modelling must be able to accommodate all kind of information required to model specific processes of the enterprise. Processes emulation for verification and acceptance of equipments and controllers, operators training, re-engineering processes require the description of totally different enterprise data and behaviours that have to be re presentable in the models.

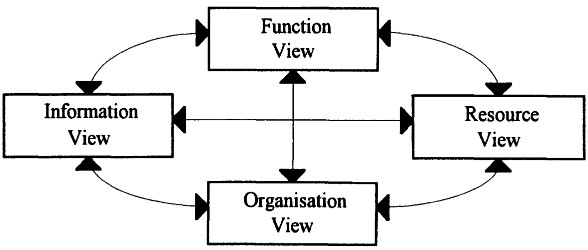
3 BENEFITS OF USING CIMOSA

Looking at the state of the art in the process modelling methodologies to find a methodology matching most of the above requirements, the actual scenario doesn't give satisfactory answers. There are many methodologies but no one is a world-wide standard and is really comprehensive. Often methodologies are just tools linked to methodologies assumed as reference. Often too, the methodologies cover specific aspects of the reality and not the whole complexity: they develop primarily a process or a view of the enterprise and a marginal relevance is left to other processes and views. As a consequence, when an enterprise process is to be analysed from different points of view, many models (information model, functional model, organisation/chart model) have to be created using different tools.

CIMOSA has been demonstrated to be capable to offer the solutions of all the above problems through the concepts of:

- Modularity,
- Integrated Approach by Views,
- Stepwise Derivation and
- Re-Usability.

Integration of Views



gives Integrated Answers in Terms of Multi-Aspects/Multi-View Anaysis

Figure II.3a The Integration of CIMOSA Views.

3.1 Modularity

Modularity is supported by the CIMOSA Building Blocks (especially Domain, DP, BP and EA) and by the definition of standard contents and standard interfaces among the Building Block's. The benefits due to the modularity that had been experienced in the FIAT pilot implementation were modelling easiness, reduction of modelling efforts and costs, maintainability and re-usability of models and models parts.

3.2 Integrated Approach by Views

The integrated approach is related to the capabilities offered by CIMOSA to describe a system in terms of Function, Information, Resource and Organisation Views, all related to each others. Such integrated approach is based on the concept of a structured integration and a conceptual separation of the Views. This allows co-design activities among experts of the different disciplines giving to each of them, in the mean time, a separated description of the information pertaining its particular field of expertise.

Examles of an integrated reply

Necessary Information	*Dynamic Behaviour*	*Process Re-Engineering*	*Resource Utilisation*	*Department Organisation*
Lead Time Throughput	*Cost*	*Productivity*	......	......

Figure II.3b The Integration of CIMOSA Views.

The obtained benefits are a better understandability of the different aspects related to the enterprise processes and the views related to the enterprise functionalities and an enterprise model optimisation across views and processes. Figures II.3a and II.3b explains the application of the above concepts in the solution of a simple problem: getting integrated answers to question concerning different processes and different views. Another advantage of the integration of the views is shown in Figure II.4.

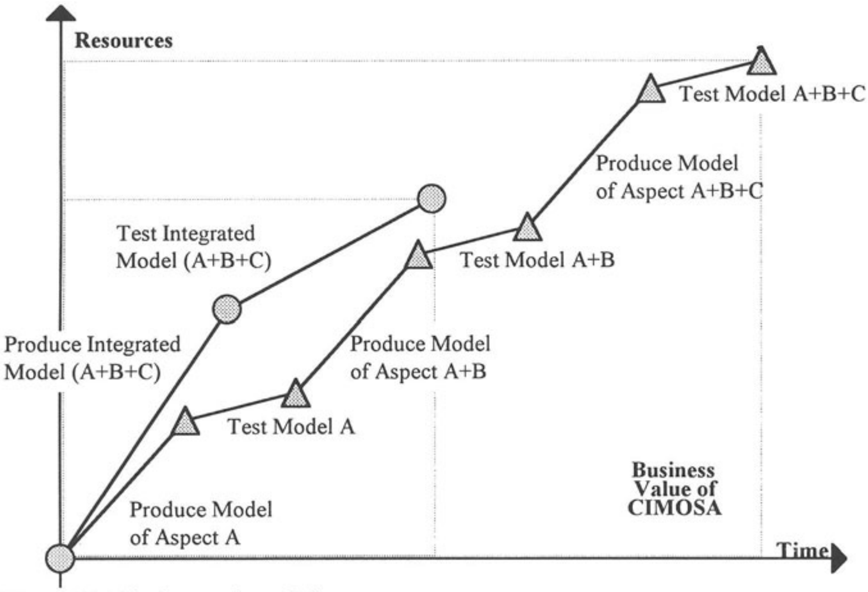


Figure II.4 The Integration of Views.

Often, in actual modelling practice, the analysis of a reality starts with the analysis of just one view (Function or Information or Resources or Organisation). Then the same reality needs to be analysed from another point of view: a new model is to be built and validated. It may be easily understood that making many models that focus on just one view and develop the other views as marginal "attributes" of the main one, duplicate efforts so, the time-by-resources area that in Figure II.4 is saved by making just one integrated model, represents a Business Value of the CIMOSA approach.

3.3 Stepwise Instantiation

The stepwise instantiation of building blocks allows to obtain models of simple and complex functionalities derived by customising the corresponding building blocks of the model at higher level of generality. In the way shown by Figure II.5 and II.6, it was possible to derive, in the implementation of the FIAT Gearbox Assembly System Model, all the 340 Particular Building Blocks used to model the pilot at any level of complexity (Domain Processes, Business Processes, Enterprise Activities) just from 6 Generic Basic Function Types and 17 Partial Models of Standard Function Types. Figure II.6 also shows the relations between the different parts of the model and the different contents of the particular model of the gearbox assembly and its runtime version (Model Occurences).

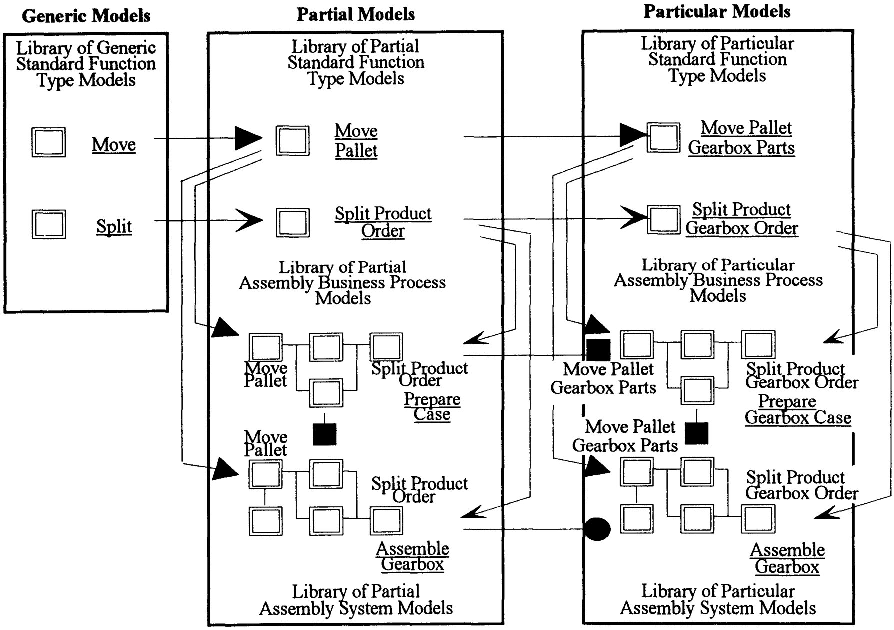


Figure II.5 Stepwise Instantiation and creation of Partial Models.

3.4 Re-Usability

This performance was also due to the application of the concept of RE-USABILITY that allowed to re-use the same Building Block's (even complex Building Block's like Domain Processes and Business Processes) in different parts of the model, instantiated with different names. The benefits of the re-usability are shown in Figure II.7.

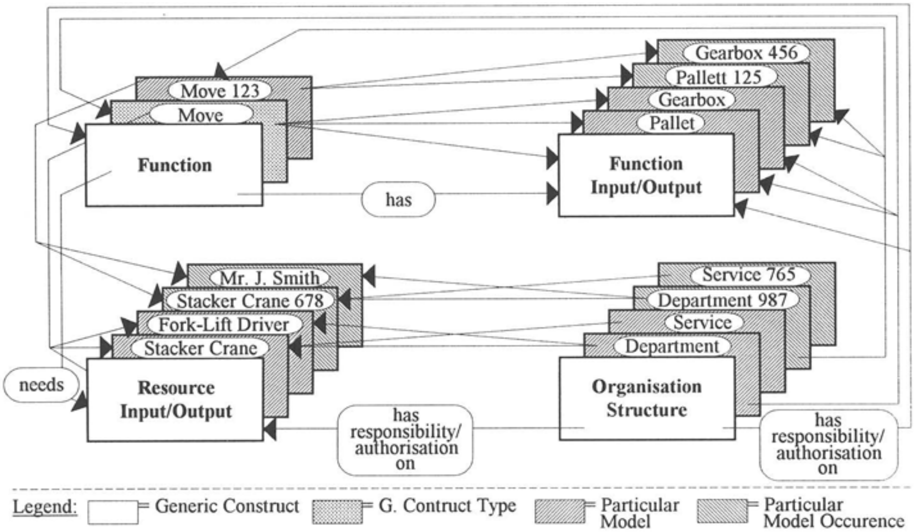


Figure II.6 Stepwise Instantiation and Relation between Views.

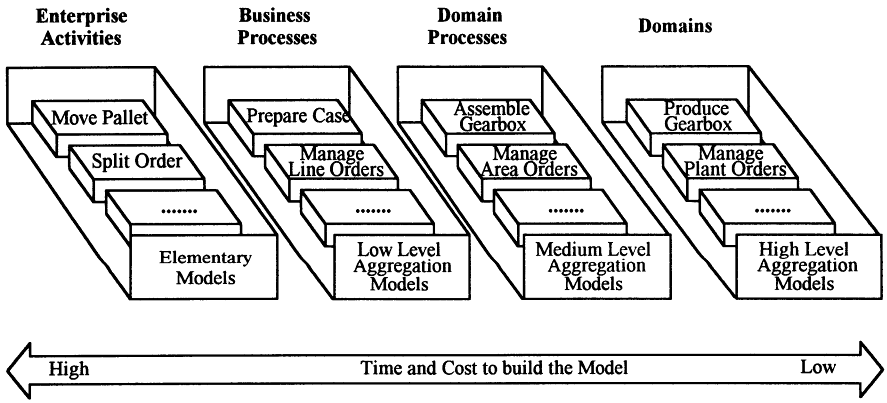


Figure II.7 Re-Usability of Models.

3.5 Business Benefits

Another benefit of the utilisation of the CIMOSA Methodology is the feasibility of the model optimisation by Objectives and Constraints. CIMOSA requires the definition of the modelled functionalities in terms of planned Objectives, imposed Constraints and the if-then-else combination among them. Such set of information has been recognised to be useful for a computerised evaluation of the simulation results by a decision making tool in order to ensure that the modelled production system meet the predefined goals (in terms of productivity, quality, costs, resource availability).

The experience of utilisation of CIMOSA Concepts applied to the ARTIFEX[3] modelling of a real environment has provided evidence of the following Business Values of CIMOSA:

- Enhancement of the quality of the analysis,
- Reduction of the analysis and validation lead times and costs and
- Additional targets for application of CIMOSA.

Table 1 General Experience of using CIMOSA.

Enhancement of the Quality of Model Analysis	
Integration of the Views provides better Simulation Capabilities	
State of the Art	**CIMOSA Models**
Information embedded in Functionality	Information structured by specific Building Blocks described at Data Base level
Organisational Structure treated as Technological Structure	Organisational Structure modelled by specific Building Blocks
Resource description embedded in Functionality	Resources described and structured by specific Building Blocks

As shown in Table 1, the integration of the Views allowed by CIMOSA has brought enhancement of the quality of the analysis with respect to previous modelling practices regarding the Information, Resources and Organisational descriptions. A comparison among the lead-times and efforts required in the past to model a productivity system and the lead times and costs to model the same system, in a "coteris paribus" situation, using re-usability of step-wise derived models has given the figures shown in Table 2.

As important as the general improvements of enterprise modelling obtained with CIMOSA are the significant reduction of modelling lead-time which have has been obtained as well. A reduction factor of 3 times in the time to build an ex-novo model and a reduction factor of 8 time to adapt a model to a similar plant have been experienced.

Table 2 Specific Experience of using CIMOSA.

Reduction of Model Creation Time and Lowering of Analysis Cost		
Benefits are Proportional to the size of Libraries of Re-Usable Models		
	State of the Art	**CIMOSA Models**
Time to build ex-novo the FIAT Model	about 6 Month	about 2 Month
Reduction in Model Engineering time		3:1
Time to re-use the Model in a similar Plant	about 4 Month	about 15 Days
Reduction in Model Engineering time		8:1
Obtaining these Factors depends on	Kind of Enterprise Reality to be modelled (and the know-how about it)	
	Availability of Elementary and re-usable Models	

3 ARTIFEX is a software product of ARTIS s.r.l. Corso Cairoli 8, 10123 Torino, Italy

4 CONCLUSIONS - EXPLOITATION IN BUSINESS ENVIRONMENT

Using CIMOSA in FIAT in a pilot implementation has shown significant business benefits both in model engineering time and in model analysis capabilities.

The structuring concepts of CIMOSA enable a clear separation of the different operational aspects (function, information, resources and organisation) during the model engineering process, but still keeping everything as part of the same model. This concept of views reduces model complexity and thereby enhances significantly model engineering efficiency. In addition, re-usability of modelling constructs has contributed very heavily to reduction in model engineering time for modelling similar or related operations. Establishing a library of standard building blocks (or building block types) as well as partial models has proven to be key in enhancing model engineering efficiency.

This experience leads to the recommendation for development and subsequent standardisation of industry-wide applicable building blocks and partial models. Only if sufficient standards have been established can models be used efficiently and effectively in enterprise operation across enterprise boundaries. This will enable optimisation of the own enterprise operation recognising the impact of supplier and customer operation as well. Standardisation in the area of enterprise modelling is also expected to decrease computer illiteracy and increase awareness on the enterprise operation and recognition of the impact of specific contributions by the individual employee.

CIMOSA based enterprise models provide a much wider scope for analysis of business alternatives. The specific model of the FIAT gearbox manufacturing operation could be used to evaluate different manufacturing scenarios. Pure push and pull-type (Kanban) strategies as well as combinations of both strategies with different change-over points could be analysed with the same model without model re-engineering. The FIAT operation can be optimised for a given set of constraints on Turn-Around-Time, Work in Process and Work in Stock by identifying the change over point from push to pull at a particular process step.

The experience made has outlined that all the above benefits may also be obtained in other fields rather than CIM only. The Experiments under execution are showing that the generated Elementary Standards Function Types are suitable to be easily adapted to other non-Manufacturing Environments (Accounting, Logistics, ... by changing the associated structure of the data.