System Dynamics Analysis , a Prototyping tool for Production System Design

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Abstract

Streamlining a production process, shortening leadtimes and sqeezing inventories and cost are the highlights of any company restructuring.Efficient factory planning is in the end usually good logistic system design. But to master the many concurrent problems of an efficient logistic system design in a company it either takes time to digest all the local improvements or one needs an integrative method to structure these intertwined problems.

Applying SDA opens the second method, which consistently proved to be faster and more efficient. This also includes the problem of proper embedding the MRP-system .Analysis of the process-chains of an important machine-tool production including sales and supply is reported as an illustrative exemple.

The Problem

A profitable production and higher CIM-levels have been and are mostly taken as synonymous.There exists a well documented body on the numerous positive and negative experiences along the way.

Wildemann (1989) ,in a major cooperative effort among some hundred companies in Germany has extracted a few main critical success factors and pitfalls:

Vertical Integration of CIM and business strategy. A horizontal approach in computer-applications to a business will create a finally non-integratable sum of CIM-islands.
Vertical integration means a top-down application within strategic business units.

Leadtimes and Throughput-times are the backbone of productivity-control. They are defined and controllable in process-chains only. A necessary condition of reducing throughput-time is therefore getting the production organized and imaged as a process-chain.

Chaotic production has attracted high application of MRP-systems, centering on control of data instead of process. Typical time frames are mostly several work-weeks.

Order of applying CIM and structuring the process should start with structuring of the process. But it has been tried often in reverse order, especially when only the restricted time horizons of an operational view were considered.

In production there are at least two distinct time frames:

operational production/process:shifts to weeks
production strategy/control:quarters to years

A conclusion on some current procedures to solve the problem extracted from the experience base of Wildemann (1989) are:

A. Evolution in small operational steps:
it takes a long time, resulting in a weak overall focus.

B. Replace existing with new infrastructure in one turnaround:
it only takes a short time, but current and future expense in not in control, because only after installing hardware and software the problems come up

C. Integrate new structure stepwise to new production-strategy (months to years):
it takes a stable master-plan and one has to avoid adjusting the organisation to a software unchecked in order not to fall into the trap of CIM-overkill.(see procedure B)

What is wanted would be a method to establish a master-plan and solve the problem of adjustement of the CIM-systems and the organisation in a direct approach.

The Prototyping Procedure

As Moody and Leonard (1990) show, defining a production strategy starts with its integration into the total business-process, e.g. fig. 1

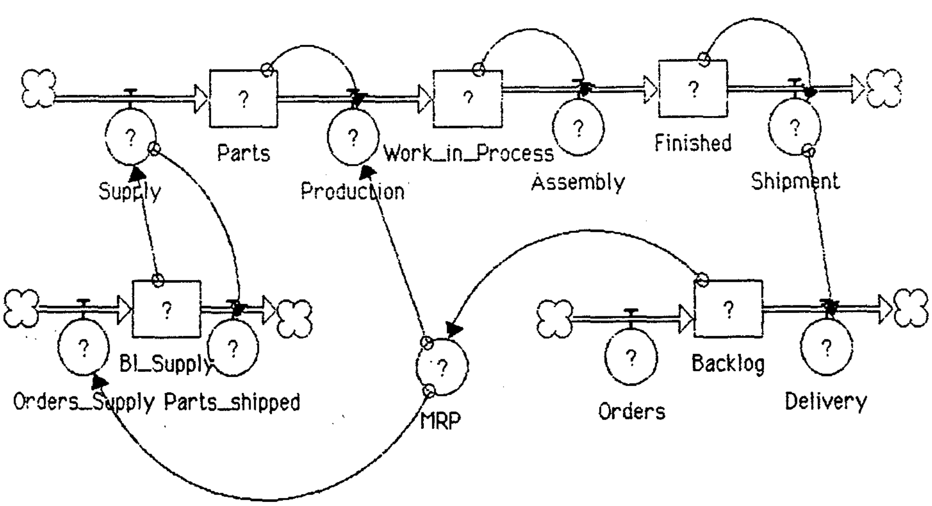

Fig.1 A company's simplified process-chain

The current trends of flexible manufacturing are changing the product/process matrix from the diagonal in fig.2 to a mostly continuous flow orientation even for unique products.

	Unique product	Multiple product	Major products	Standard products
Job shop	x			
Batch		x		
Assembly line			x	
Continuous flow	o	o	o	x,o

Fig.2 x showing traditional,o showing modern trends of manufacturing Produkt/Process-Matrix, Moody (1990)

The goal of prototyping is assumed to define the optimum production-process, including every step from supply until final payments of clients.An exemple of a target figure to attain would be the asset turnover.

Maximizing asset turnover AT means therefore optimizing the whole process-chain, not the production process only .Fixed assets and current assets are influenced differently by the requirements of capacity load, flexibility and leadtime.

An optimum capacity load does minimize fixed assets whereas short leadtimes minimize current assets. But to arrive at a common minimum under the additional condition of flexibility, the total business-process and its control-logic have to be optimized.

Modelling the Business-Process

To tackle this optimizing work in an efficient way, we need a suitable model of the process, that keeps track of the interrelationship of the control-logic, the stocks and the leadtimes.In addition we would favor a model which allows to cope with repetitive operations, supporting our goal of cost minimizing.We propose to use modelling the business process as a structured process-chain, e.g. structured after the parts-tree of an assembly operation.

Our main working assumption is,that by proper simplifying, any business-process may be modelled as a process-chain of concatenated single process-steps. By treating sub-systems, which do have variable chaining, such as discrete logistics operations as integral entities, we arrive at homogenous quasi-continuous process-models.By verifying the existing business-process station by station for input, output, leadtime and control-connections, the building blocks of it are identified, see fig. 3.

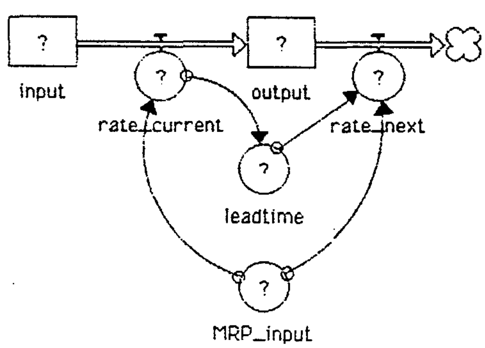

Fig.3 Model building block

Just because we concentrate on parameters such as stocks and leadtime and its connection to the control-logic treating the process as a continuous flow is a fair approximation even with an itemized production of individual units (cars,machines,etc.). This is further justified in most cases by the accounting procedures following the process proper.

A first result of such an analysis of the business-process is the model of its different process-chains, showing all the concatenated process-steps with stocks, work in progress and controls including client and supply.From this model the stocks with integrated values, operating cost and capacity loads are given at any moment in time.It is not a model of information-flow or materials-flow, but their integration with the overall control-system.

Such a process-model, as illustrated in a much simplified version in fig 1 is the basis from which to start analysis of dynamic behaviour in order to optimize structure and control-policies.To do so, we advice to follow a clean top-down approach. Only after having arrived at an optimized structure and control-policy a more detailed system design is started with sub-systems.Especially so for sub-systems, that are not suitably amenable to treatment by continuous simulation tools.

Such sub-systems belong to the important class of logistic distribution and other automatized processes, that are internally coupled by local event-logic. Simulation analysis of this class of sub-systems is to be done using the discrete simulation tools available (SIMPLE,SIMFACTORY,etc.)

The top-down approach proposed supports further analysis of such discrete sub-systems by establishing their optimum integration into an overall control-policy of the embedding process.

Such a business model will cover the total leadtime from supply to clients payments and will be used to show the simulated behavior over several times the total leadtime, mostly months to years.

Referring to fig.2 we will encounter the following situations amenable to continuous flow models:

Type of Production	**Characterized by**
Chaotic single order	limited process step number
Flexible line	limited parts-tree-list number
Mass production	limited options-tree number

The justification to bypass at the moment discrete-event modelling is drawn by our focus of interest:We want to optimize first control-loop architecture, flows and stocks within the long time horizons of optimum production strategy.Scheduling, capacity of equipment, etc. are treated later on subsystems-level and within the time horizons of operational production.

MRP-system integration into the continuous model is simplified as a forward or backward scheduled control signal at specified process-steps.Going one step further output of MPS could be detailed, resulting in variations to MRP input for test purpose. See further comments below for embedding discrete-event submodels.Fig 4 does summarize the timing situation for a backward scheduled MRP-signal.

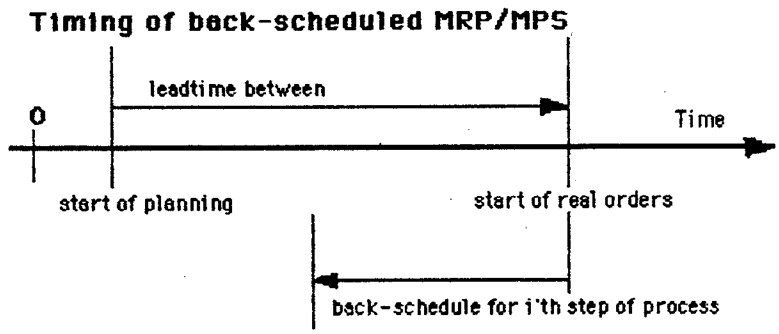

Fig.4 Timing situation MRP

The DYNEX-model

A DYNEX-model is available based on a real company case to demonstrate the results of a process-chain-analysis with a user friendly interface. Once the model is running, an expert prepares the input-tree of parameters that are critical and defines the setup of a USER-GAME.

In the DEMO-DYNEX this input tree covers the following parameters:

1.set input-signal of planned sales program
2.set real differences of sales plan (forecast) to actual sales
3.set man-weeks per unit
4.set leadtimes in production
5.make choice of variables display

After this operational parameters we define policy parameters also:

6.Do suppliers deliver by net-volume-control
7.or backwards-scheduling of orders to suppliers
8 choice of adding error from deviations
  -with backwards smoothing filter
  -by adding as capacity control
    -with additional smoothing for assembly line

The Policy-Choices cover the methods to add an error correction to a planning.There are two choices available:

Progressive filtered deviations

In order to make a forecast, you have to go into the past an equal amount of time.To create a useful forecast for input to a back-scheduling MRP, the deviations between planned and actual output are progressively filtered and averaged with increasing amount of back-scheduling e.g. a stage immediately before orders gets as correction the almost unfiltered difference.

Capacity-mode correction

A very different policy is to add to the backwards scheduled planned operation a simultaneous add-on control at every stage involved. (a so called "capacity-control") For cases ,where the difference of real orders and planned orders is small compared to planned orders, such a policy is usually superior to the progressive filtering.

Fig.5 and fig.6 are an exemple of the DYNEX-output,comparing the two policy choices for a ramp-signal as difference between planning an actual orders.The capacity-mode proves to be superior for tackling deterministic deviations,because the whole process-chain is corrected.D=demand.FIV=finished inventory sales,SRC=delivery rate at factory outlet.The first 40 weeks show filling of the pipeline.From week 40 on we have normal operation, also the ramp-deviation starts.

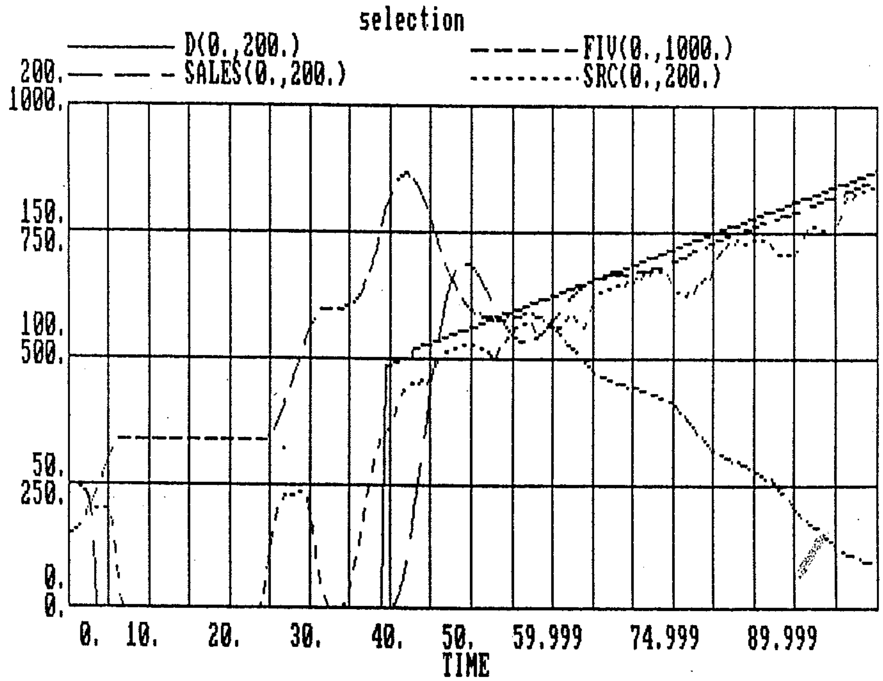

Fig.5 Capacity-mode correction, even SRC is following D

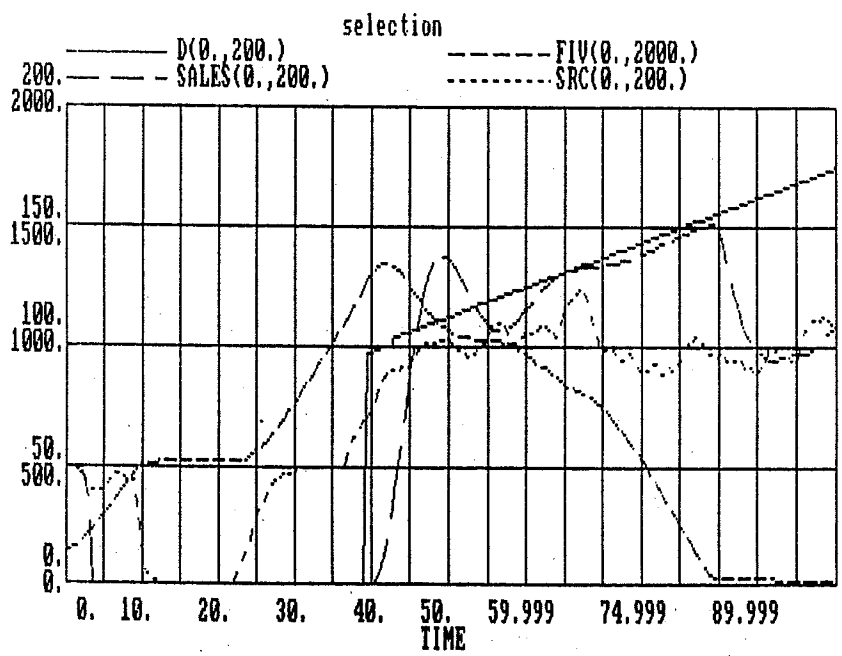

Fig.6 Progressive filtering.After exhausting FIV even SALES does not pick up in time

Embedding discrete-event submodels/working assumptions

Using SDA as a prototyping tool for factory-control-policy is based on the working assumption, that for almost any production process a reasonably precise continuous top-down model can be defined. As Kettenis (1992) puts it, depending on the granularity of the model necessary, there exists always a continuous model for any process.

This assumption is in line with two observations in the field:The trend to continuous flow strategies for modern, efficient production, see Moody (1990) results in process-chain structures clearly amenable to continuous models.

As a recent treatment of the problem of combinations of discrete-event and continuous simulation shows, it is a continuous simulation with its inherent activity scanning every time step DT, that can be used as top-level integrating background, see Kettenis (1992).This is concluded from Kettenis discussion of the four worldviews of simulation below:

Worldview	**exemple of simulation language**
Next event	SIMAN,SLAM
Activity scanning	DYNAMO
Process interaction	COSMOS,SIMPLE,Petri-Net
Transaction flows	SIMAN,SLAM

With the still limited experience in the field a very preliminary assessment of compatibility for embedding discrete-event and continuous simulation will expect less problems with process-interaction languages than with next-event or transaction flows languages.

We include below an abreviated definition of these four world views:

Next-event	sitting on top of process with event-timer
Activity-scanning	checking every time step all the variables
Process-interaction	checking every time step the process interacting variables
Transacions-flows	sitting on the workpieces with the joblist

To illustrate practical embedding already used, the following cases are shortly discussed:

- -MRP-systems
- -a comissioning application
- -small lot size chaotic
- -line-flow with different products
- -general interface discrete-event/continuous

MRP-system modelling in SDA

The MRP-systems function is coupling of the planning MRP II with the more detailed execution MPS.

In the most simplified form, the input signal of the planning and the execution are identical. In general MPS is a transform of the MRP II planning input, showing volume, attribute and timing differences for the execution back or forward scheduled control signals.

In a continuous model the MRP-system comprises the control signal generator e.g. as the sum of the planning and the variances of the translation in the MPS.

With discrete-event type execution level we will image its statistical properties into the continuous top-down model.

A commissioning application

(a typical discrete-event type of problem)

A possible continuous structure to capture a mechanized stock with commissioning station could be as in fig.7

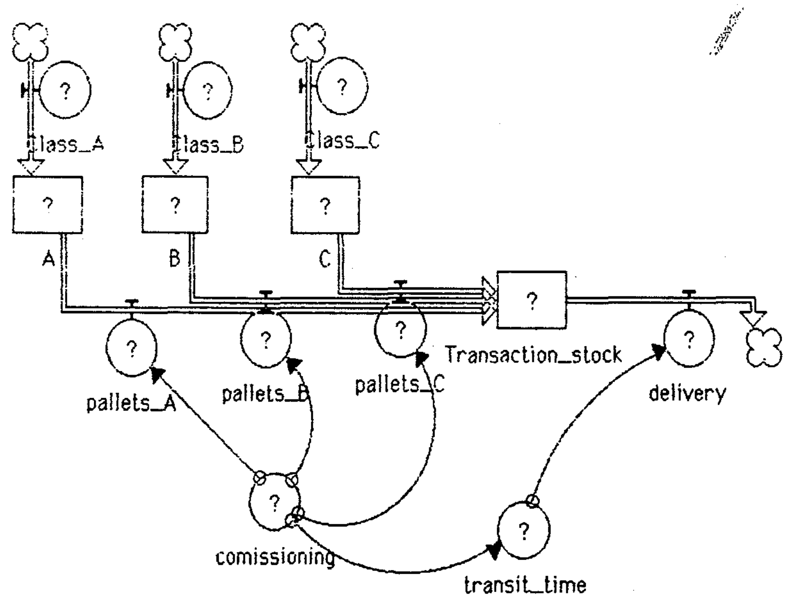

Fig.7 Class-separation for continuous simulation of commissioning

Small lot size chaotic production

With an upper limit to the kind of process steps used, e.g. as in producing printed circuit cards a continuous model would be a stack of the different process-chains with vertical connection of common capacities.

Production line with different products

A common process-chain with parameters such as leadtimes and capacity-limits controlled by the flow attributes is a possible model.In fig 8 we show the model of the real company case simulated in the DYNEX-case.

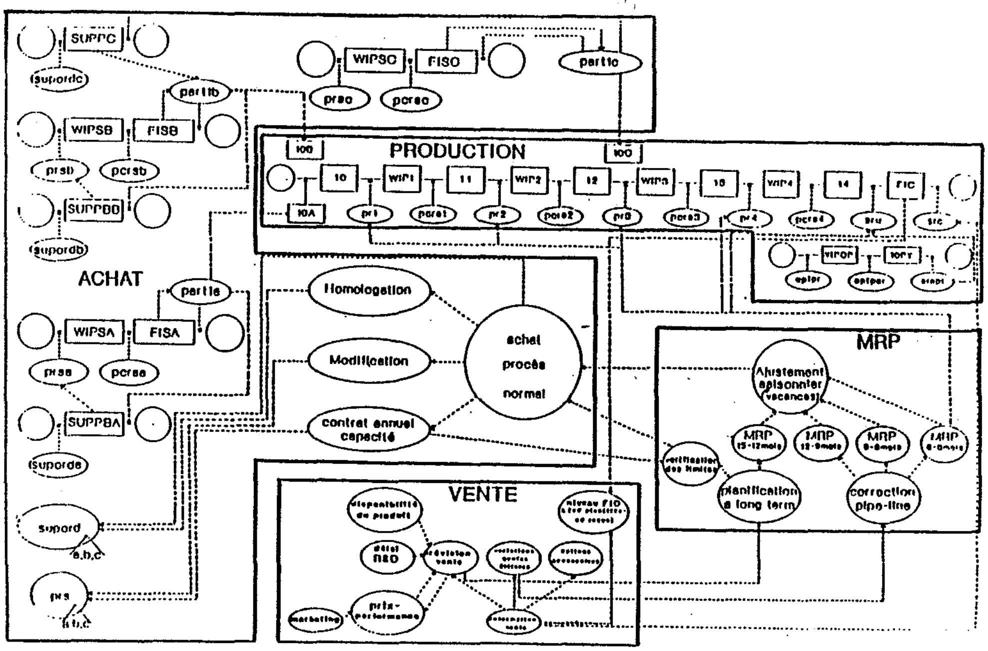

Fig.8 Model of the DYNEX case with sales and suppliers, compare to the simplified model of fig.1

General interface discrete-event/continuous

Continuous-Discrete: a unit timer operates the disaggregation of a continuous rate

Discrete-Continuous: a smoothing operation transforms discrete arrival of units into a continuous rate

In the experience of the author these above illustrated ideas how to cope with modelling so called discrete-event processes in continuous fashion have usually worked well.

Conclusion

The purpose of the paper has been to expose the possible contribution of top-down SDA models of the business-process to speed up logistic system design.

The critical sucess factors for mastering the CIM-levels increasing competitivity is asking for and the trend towards continuous flow processes emphasize use of continuous simulation tools

The CSF's were:

CIM-integration should be vertical inside business units resulting in clear models.

Time horizons have to cover several accounting periods, so top-down models are needed to economize CPU power.

Troughput-time is in process-chains defined only, a precondition to use continuous models.

A stable verifiable masterplan for CIM-integration is needed: a process-control model with simulation will fill the bill

To effectively support logistic system design by a simulation tool. there is a choice of four world views available:

Next-event
Activity-scanning
Process-interaction
Transactions-flows

As we have seen the Activity-scanning view is the choice for top-level overall models, which means a continuous simulation (solving a system of simultanuous differential equations)

The need to model the control-logic first. before going to more detailed subsystems again points to use of a continuous model.Not all world views can be combined afterwards easely with a continuous simulation.

A preliminary assessment identifies Next-event and Transactions-flows as rather separate world views. SIMAN and SLAM belong to that class, which resembles more to the approach taken by MPS-calculus itself.Others , such as COSMOS, SIMPLE, and the general class of Petri-Net-Languages appear however to be relatively easy to integrate with continuous models.

Speaking of control-logic we understood this to be control-loops of a continuous model. In discrete-event models one uses the word Control-strategy meaning the logic of the discrete state changes of process elements.

A main proposition explained in the paper was , that in any case of a logistic system design we neeed to cover two rather different tasks:

A. Business-process-control with long time horizon
use a model with coarse granularity to bring out the dominant control loops. The choice tool is a continuous model with flows, leadtimes and stocks

B. Operations-process-control with short time horizon
use model with fine detail to bring out intra-process control-strategy.Application of discrete-event tools for capacity and scheduling.

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Trade names

SIMAN,SLAM,SIMFACTORY,COSMOS,SIMPLE,DYNYMO are trade-names of software for simulation cited in the text