“ Finity: An Integrated Solution to Production Planning and Scheduling in Process Manufacturing Industries.”

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Abstract

Process manufacturing represents more than 50% of the world’s total manufacturing business. However, commercially available software provides little support for the unique production planning and scheduling requirements of this industry category.

Finity is a vertically integrated software solution designed specifically for process manufacturing, with best-of-breed functionality in the areas of demand forecasting, inventory modelling, production planning and scheduling, cost allocation, activity based costing and real time schedule execution.

Finity makes extensive use of iLog libraries, including the iLog Optimisation Suite for the planning and scheduling functions, and iLog Views for User Interface functions.

Finity has been installed in a number of sites in the food and beverage sector, and has been designed to be easily configured for use in a broad spectrum of process industries.

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Introduction

Finity is a Finite Planning and Scheduling software product designed to support the unique requirements of Process Manufacturing Industries.

Finity was jointly developed by Uncle Ben's of Australia and QED International, for the Uncle Ben's PPS (Production Planning and Scheduling) project. The software has been successfully installed at one site, and is currently being implemented at another. Uncle Ben's of Australia, a company of Mars Corporation, manufactures pet food at two Australian sites.

QED International is a Sydney based software company that specialises in Supply Chain Planning and Scheduling software.

The Finity Philosophy

Finity is based on two fundamental tenets.

Firstly, process manufacturing is not well served by currently available scheduling products. Those products are typically based on the traditional material requirements planning (MRP) logic that is more suited to discrete manufacturing industries. Finity utilises a Process Flow Model that more precisely fits the needs of process manufacturing.

Secondly, conventional planning and scheduling methodology utilises an hierarchical approach, with long term, medium term and short term planning decisions taken as separate sequential steps. This can result in infeasible plans being imposed on the scheduling phase. This is particularly problematic in process manufacturing, where capacity cannot me modelled with sufficient accuracy at the higher planning levels, thus increasing the likelihood of infeasible and sub-optimal plans. Finity integrates the planning and scheduling function, thus ensuring feasible and optimal plans.

These two fundamentals of Finity philosophy are examined in the following sections.

Scheduling in Process Industries

Manufacturing environments

Manufacturing operations can be divided into two basic environments. These are often referred to as "explosion" manufacturing and "implosion" manufacturing, or process manufacturing and discrete manufacturing respectively. Explosion manufacturing refers to the processing of one or a few raw materials into a wide variety of finished goods, while implosion manufacturing refers to the assembly of a wide variety components to produce the finished goods.

However, there is no clearly defined boundary between these manufacturing environments. Indeed, Taylor and Bolander [1] describe a continuum between the two extremes. Further they discuss the impact of both the Marketing Environment and Manufacturing Environment on planning and scheduling systems. In fact, they identify both the product (or marketing) environment and production environment, and map business on a matrix with these two axes.

Marketing environment

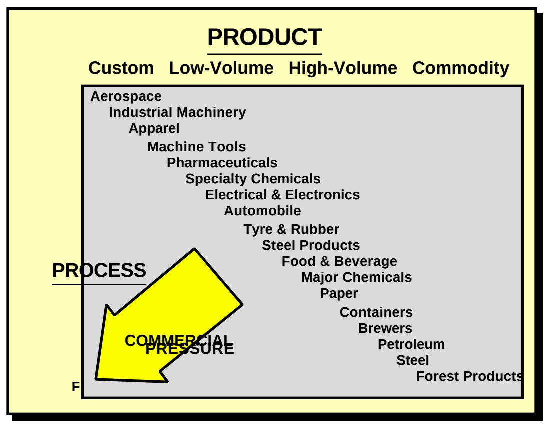
"One of the most important factors in developing a business strategy is differentiating a be viewed as a continuum. Custom products are at one end of the spectrum, and commodity products are at the other end. Industry groups and individual companies often have products at several different points along the product differentiation spectrum."

Production environment

"Manufacturing facilities can also be classified along a continuum, with job shops at one end and flow shops at the other end. A job shop is a manufacturing facility in which materials flow through the shop with routings dependent on each job. A flow shop is a manufacturing facility in which materials flow through the plant with a fixed routing. Most manufacturing facilities fall somewhere between a pure job shop and a pure flow shop."

Product - process matrix

"A firm's manufacturing facilities need to fit its marketing environment. The accompanying diagram shows a product-process matrix. Horizontal positions on the matrix represent the degree of product differentiation discussed in the above section on marketing environments. Vertical positions on the matrix represent the process spectrum including job shops and flow shops. As shown, most industries tend to fall along the principal diagonal of the product-process matrix. Notice that process (explosion) industries tend to fall in the lower right portion of the matrix, while fabrication and assembly (implosion) industries tend to fall in the upper left.



An individual firm's position on the product-process matrix relative to the position of its competitors can be an important factor in a firm's business strategy."

Marketing pressures tend to move firms to a higher level of product differentiation, ie. to the left of horizontal axis. Pressures on manufacturing costs push firms down the vertical axis.(We have illustrated these pressures with the arrow on the matrix.) Taylor and Bollander describe it thus:

" Ideally, therefore, a firm will move off the diagonal and toward the lower left corner of the matrix, providing increased product variety together with the efficiencies of flow shop production."

These commercial pressures therefore are tending to make the scheduling problem more difficult, and are certainly representative of the pressures experienced by Uncle Ben's that led to the development of Finity.

Process Flow Scheduling

Taylor and Bolander [1] outline the difficulties of production scheduling in process manufacturing environments, and explain the reasons why scheduling methodologies used in discrete manufacturing are unsuited for these environments. They then propose a model for production scheduling in process industries that they term “Process Flow Scheduling”.

Finity utilises a model designed specifically for process industries that is very similar to the model described by these authors.

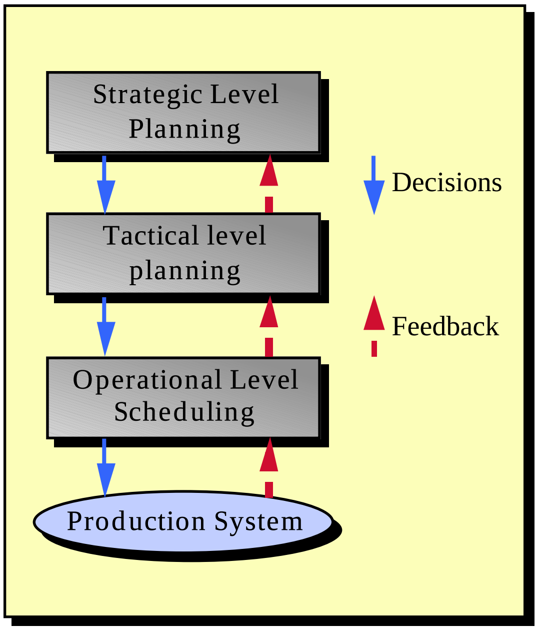
Planning and Scheduling Methodology

The production planning and scheduling process is often described using a three level model, as shown. These three levels are typically called:

- strategic, or high level, planning
- tactical planning
- production scheduling (operational planning)

Alternatively, these levels are referred to as long-term, medium term and short-term planning, reflecting the respective time horizon of decisions at each level.

The reason for this multi-level approach is that the level of detail required at the scheduling level becomes impossible to comprehend over the longer horizons of the higher levels.



Heirarchical Planning Model

Most planning and scheduling software follows a similar multi-level model, for the same reason, ie the computing power required to process the detailed scheduling data over a long time horizon has been beyond the capabilities of available hardware and software technology.

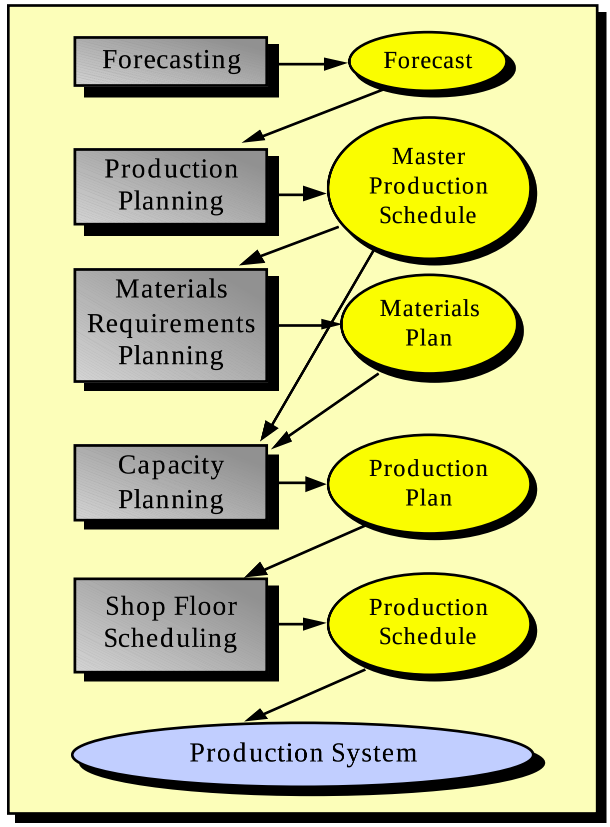
The fundamental flaw in the conventional three level model is that decisions made at each level become constraints upon the next level. This can result in plans that are infeasible. Even if feasible, such plans are unlikely to be optimal. The infeasibility issue is often addressed via a simplistic Capacity Requirements Plan (CRP), but this does not address optimality of the plan. The CRP function is typically a Yes/No decision based on a rudimentary capacity model. Some functionality may exist to manipulate the plan until the capacity check is passed.

In reality, the planning process is divided into many functional components, with multiple supporting “plans”. This is illustrated in the following conceptual model.

The problem of infeasibility is particularly problematic in process industries, as it is difficult to model capacity with sufficient detail to improve CRP results. Sub-optimality of plans is also a problem, as this results in inefficient utilisation of expensive resources, plant and equipment.

Plossl [4] presents one of the basic principles of planning as:

> **“Stand-alone, independent and multipurpose plans are worse than useless; they are dangerous.”**



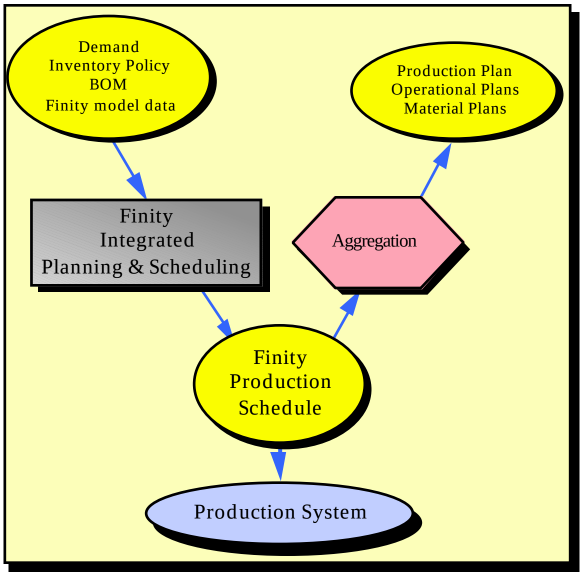
Typical planning model with multiple plans

Several recent research has aimed at integrating these two levels planning. Stephan Dauzere-Peres and Jean-Bernard Lasserre [2] propose an integrated model for planning and scheduling decisions to address the consistency issue between the tactical and operational levels, by ensuring that the production plan is feasible, that is, there exists at least one feasible schedule compatible with the plan. It is important to note that only the existence of a “feasible schedule” is considered. Their solution is an iterative procedure which alternates between solving the planning problem for a fixed sequence, and solving the scheduling problem for a fixed plan. This sequence continues until a feasible solution is found. Several key points should be noted. Firstly, no attempt is made to find “better” solutions, let alone optimal ones. Secondly, the solution proposed and examples given are for job-shop scheduling, not process flow scheduling. Finally, the scheduling problem is solved using simulation techniques, a technology that was dismissed in the design of Finity.

Finity utilises an integrated approach to solving the planning and scheduling problem, similar in some ways to the recent research described above. The general planning approach of Finity is shown in the diagram below.

Finity has been designed to Integrate the (Tactical) Planning and Scheduling (Operational) functions. The Process Flow Modelling and Incremental Optimisation technologies in Finity, combined with recent developments in hardware and software, enable Finity ultaneously generate detailed schedules over extended time horizons.

The Finity Integrated Planning and Scheduling model is shown in the diagram. Finity generates detailed schedules over the entire planning horizon, optimally allocating production resources to each production activity necessary to meet forecast demand. These detailed schedules are then used as the basis for all planning activities, eg operational plans, material plans. **Plans and schedules are thus different views of a single entity, ie the feasible, optimal production schedule.** This eliminates the danger highlighted by Plossl of having independent, multi-level plans. Finity always deals with a single, feasible, optimal plan.

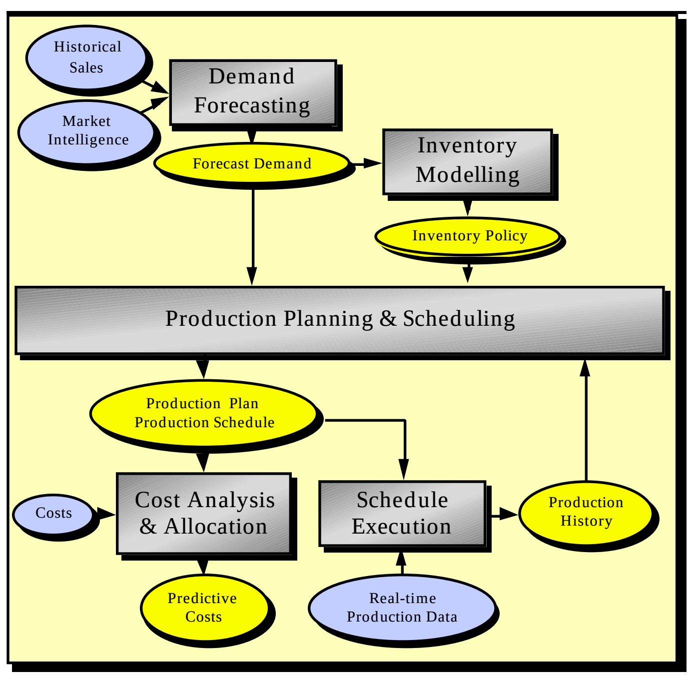


The Finity Planning Model

Finity: An Integrated Solution

Finity Overview

Finity was developed in response to a client's requirement for a solution to the general planning and scheduling issues described above. Finity comprises a vertically integrated suite of software modules, as shown in the following functional architecture diagram.



Vertically Integrated Solution for Process Industries.

The primary modules of Finity are:

- Integrated Planning and Scheduling
- Demand Forecasting
- Inventory Modelling
- Cost Analysis
- Schedule Execution

Integrated Planning and Scheduling

This is the core module of Finity. It comprises integrated planning and scheduling functions based on a manufacturing model designed specifically for Process Flow Scheduling, as described in previous sections.

Primary inputs to this module are demand forecast and inventory policy (refer below).

Outputs from this module drive the schedule execution and reactive scheduling functions, which are also core functions of Finity. In addition, these outputs are typically directed to other systems, such as cost analysis and allocation, material planning etc, which may be external to Finity.

Demand Forecasting and Inventory Modelling

Demand forecasting functions utilise historical demand data plus customer orders, management policy and market intelligence to generate a time phased production demand for each product. Complex statistical technology is used to generate this data, which is a primary input to the planning and scheduling module.

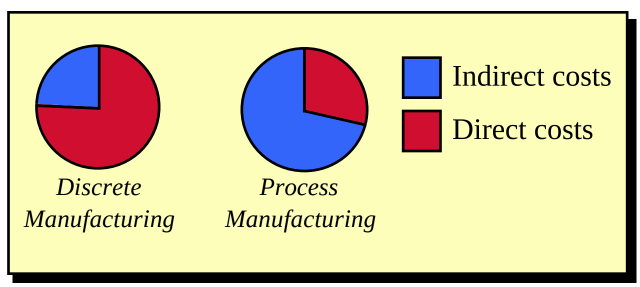
The inventory model generates target stock levels of each product to minimise inventory investment while respecting management objectives of customer service levels. This is also a primary input to the planning and scheduling module.

The third major input to the system is initial inventory levels of each product.

These inputs are combined to determine production requirements (production requirement for each product = initial inventory - production forecast + target stock level)

Cost Analysis

A characteristic that differentiates the two manufacturing environments is cost structure. As a percentage of the value of the finished goods, products from process manufacturing tend to have a low proportion of direct cost (raw materials, direct labour etc) and a high proportion of indirect cost (overheads, indirect labour, etc). On the other hand, products from discrete manufacturing tend to have a high proportion of direct costs and lower indirect costs. Refer diagram.



The absence of an accurate quantitative basis for cost allocation in process industries, often substituted with a simplistic "standard cost", results in poor support for management decisions.

Finity, via its cost allocation module, provides the capability for accurate cost allocation at a manufactured item level, thereby providing a sound cost basis for decision support functions that directly translates to increased profitability.

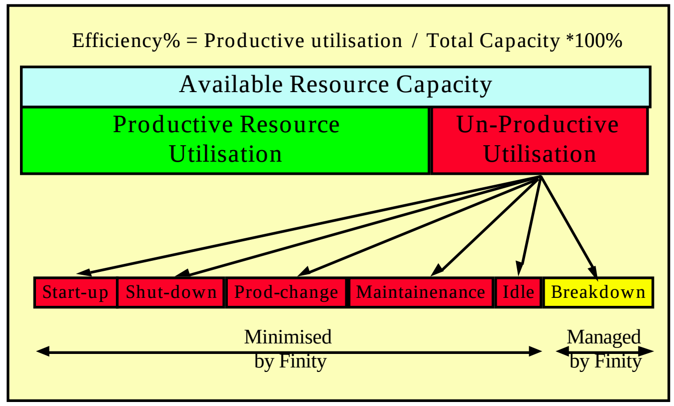
Schedule Execution

The schedule execution module of Finity manages and controls the execution of schedules. This module is typically used not only in a normal operational mode to update production on a regular (eg daily or shift) basis, but also in the event of breakdowns.

In addition to management of schedule execution, this module is a key component in the maximising of resource utilisation, or production efficiency. This is described in the following section.

Production Efficiency

Efficient use of resources is one of the primary objectives of manufacturing operations. This is particularly true for process industries, where resources typically represent huge capital investments.



Efficiency is usually expressed as the percentage of time that resources are productively utilised. Unproductive utilisation would result from activities such as transitions (start-up, shut-down, product change etc), maintenance, idle time and breakdown. All except breakdown can be anticipated, and their impact on efficiency minimised with good planning. Breakdowns are obviously not scheduled, and their impact is two-fold. Firstly, production is lost while the resource is unavailable. Secondly, in the event of a prolonged outage, a new schedule must be generated quickly to minimise the impact of the upset.

Finity provides the capability to manage every factor in the efficiency equation.

Firstly, unproductive activities such as transitions, maintenance and idle time are the Finity scheduling outputs, and are minimised by the Finity optimisation strategies.

Secondly, all downtime is monitored via the Finity Execution module. This module contains cause analysis functions to identify those events that have greatest impact on efficiency. In addition, historical performance data can be analysed to determine effective rates of processes on workcentres, which are then used by Finity when generating new schedules, thus ensuring realistic results.

Finally, the performance of Finity is such that in the event of an extended process upset, a new schedule can be quickly generated in real time to minimise impact of the upset. This capability is referred to as reactive scheduling.

Thus, Finity provides the capability to manage every factor in the efficiency equation.

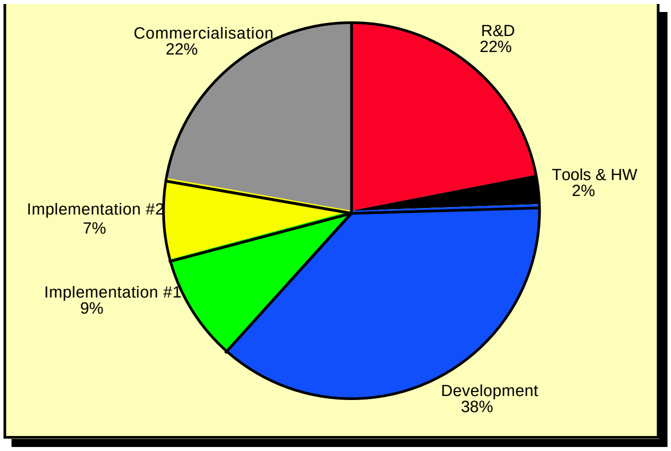
Finity Development Project

Timetable

The development of Finity spanned a number of years, as shown in the following timetable.

PHASE	FROM	TO
Research & development	Feb 1992	Dec 1994
Initial Development	Jan 1995	May 1997
Initial Implementation	Aug 1996	June 1997
Subsequent Implementation	Feb 1997	July 1997
Commercialisation	Jan 1997	Mar 1998 ++

Costs



In total, more than $US3m has been invested in the development of Finity. The approximate breakdown is shown in the following graphs.

Technical Details

Finity was developed in Microsoft Visual C++, and executes under the Microsoft Windows NT operating system. It based on the client-server architectural model. The Finity database is Oracle 7 Enterprise Server.

iLog Tools

Finity utilises the following iLog components:

- iLog Solver
- iLog Schedule
- iLog Planner (currently being implemented)
- iLog Views
- iLog Inform

A wide variety of technologies are embedded in Finity, and a number of other tools have also been utilised, eg in GUI, database and reporting functions, but iLog tools are primary enablers of Finity.

Tool selection was a multi step process.

During the R&D phase, various classes of technology were evaluated. The most promising were utilised in various prototypes. During this phase, Finity architecture and the Process Flow Model were also refined.

Having designed Finity architecture and identified the technologies required, the first step in the implementation phase was to select the specific tools. Based on our experiences during R&D, iLog Solver and Schedule were almost automatic choices for the following reasons:

1. Performance. The dimensions of the integrated planning and scheduling model is such that performance of solving tools is critical. The iLog tools were considered “best-in-class”, which was supported by benchmark data provided by iLog. Some tools required hours to days to resolve our model, when real time performance was the objective. This was delivered by iLog Solver and Schedule.

2. Ability to represent our process flow model. The iLog tools were able to represent every requirement of the Finity Process Flow Model.

3. Vendor support. During the R&D phase, iLog provided not only excellent support for their tools, but also a broad and deep understanding of the application domain. This was vital for a project of this magnitude and importance.

iLog Planner is currently being embedded in Finity to augment the optimisation capabilities in the planning area. The choice of Planner was “automatic”, as it is designed to compliment Solver and Schedule.

iLog Views is arguably “over functional” for the requirements of Finity. However, this tool was selected as it provided a fast track to delivery of the finished product. In addition, portability across operating systems was also a factor.

iLog InForm was selected for similar reasons as Views, to provide improved visibility to the Finity data model. Portability across databases was also considered important.

Summary

QED International has developed Finity, a vertically integrated software product for supply chain planning and scheduling, designed specifically to address the requirements of process industries. These industries are currently not well served by existing commercial software offerings.

The key to the success of Finity is the unique Process Flow Model and Integrated Planning & Scheduling Methodology developed by QED. The primary enabler of these Finity technologies is the iLog Optimisation Suite.

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