Integrating Shop-Floor Systems with SAP R/3 PP and PP-PI Modules – Some Recent Project Experience

Willem Dekkers  
Senior Consultant  
SAP Integrated Manufacturing  
Origin International  
Wilton Centre Annexe  
PO Box 54, Wilton  
Middlesbrough  
Cleveland TS90 8JA  
UK  
Tel: +44 1642 436790  
Fax: +44 1642 436800  
Willem.Dekkers@origin-it.com

David Faustino  
Consultant  
SAP Integrated Manufacturing  
Origin International  
Wilton Centre Annexe  
PO Box 54, Wilton  
Middlesbrough  
Cleveland TS90 8JA  
UK  
Tel: +44 1642 436790  
Fax: +44 1642 436800  
David.Faustino@pt.origin-it.com

Peter Hopkinson  
Principal Consultant  
ERP & Extended Services  
Origin UK  
Wilton Centre Annexe  
PO Box 54, Wilton  
Middlesbrough  
Cleveland TS90 8JA  
UK  
Tel: +44 1642 432391  
Fax: +44 1642 436800  
Peter.Hopkinson@uk.origin-it.com

KEY WORDS
MES, ERP, SAP R/3, Enterprise Integration

ABSTRACT

Business drivers to improve performance, such as supply chain performance and operational effectiveness, require that integration of Enterprise Resource Planning (ERP) and shop-floor systems is considered. Many manufacturing companies have implemented the SAP R/3 ERP system, supporting core business processes including financials, sales, distribution and so on. The manufacturing processes may be controlled by a combination of automatic control equipment and human operators.

SAP R/3 supports production planning functionality in its PP (standard production planning) module and sub-modules PP-PI (production planning for the process industries), PP-REP (repetitive manufacturing) and PP-Kanban. These modules support the exchange of data with external systems. However, the technology issues associated with such data exchange are part of a broader set of challenges that an integration project must address if the intended business benefits are to be obtained.
This paper examines a business-driven approach to integration and explores recent project experience integrating shop-floor systems with the PP and PP-PI modules.

1. Introduction

Manufacturing companies are under constant pressure to improve their performance and adapt to changing business models. In the globally competitive world, manufacturers are having to become more agile to satisfy demands such as faster time to market, shorter production runs and ability to co-operate in supply chain initiatives. More recently, eBusiness has compounded the rate of change necessary and is attracting a significant share of corporate attention.

Although eBusiness and supply chain business processes are the strategic issues being tackled, the successful businesses will be those that are able to fulfil the promises made at a profit. To achieve such success, the delivery promises need to be better than the competition, the business needs to be capable of making the goods and have the capacity to achieve the delivery, and costs must be under control. This requires a sound IT infrastructure supporting the business processes to meet these objectives.

This paper examines the contribution which ERP to shop-floor integration offers and describes some of the issues which arise in such projects. Key elements of an approach to identify business benefits are described and recent project experience integrating manufacturing systems with the SAP R/3 planning modules PP and PP-PI are examined. Although Origin has integrated shop-floor systems with other ERPs, such as Baan and QAD’s MFG/Pro, the particular examples in this paper refer to SAP R/3 because this is the dominant ERP in the process industries.

2. Why Integrate?

2.1 The Business Context

The extended enterprise, to which the manufacturer belongs, consists of a chain of source, make, and deliver processes, as described in the Supply Chain Operations Reference (SCOR) model [1].

These supply chains can be highly dynamic, re-configuring as business moves towards competing supply chains and contract manufacturing. The introduction of web-based trading marketplaces increases yet further the pace of change. To participate, the manufacturer needs either lots of stock or the ability to react swiftly to fluctuating demand for existing products and the opportunity to produce new products. For example, over the last few years, the supermarkets have been very innovative in promoting sales campaigns such as “two for the price of one”. These inevitably produce wildly fluctuating demand to the suppliers who either satisfy the demand or run the risk of losing the contract with the supermarket. Given the constraints of shelf life, a substantial make to stock manufacturing strategy may be impractical and may at least result in finished goods stock holding being unacceptably high, tying up capital in the inventory and increasing the operational warehousing costs.

![Figure 1 – The Extended Enterprise](image-url)
What does a manufacturer deliver to its customer? Clearly, the customer places an order for a quantity of product but, increasingly, there is at least an implicit requirement to provide, or have the capability to provide, associated information:

- In regulated industries, the product itself may be worthless without the information which verifies that the goods were produced to the approved specification, using the approved process.
- Traceability is an increasing requirement, although the customer may require the supplier to maintain the associated information until (hopefully never) required. A number of high profile product recalls have focused attention on the need to be able to trace the history of a product across the supply chain, including its ingredients, containers and logistics information. This supports more detailed impact analysis if a problem is identified, enabling a more restricted product recall to be undertaken which not only reduces the cost of scrapped product, but may also prevent damage to the brand [2].
- Invoice justification can be a sensitive subject for some manufacturers. Incorrect invoicing, because the stated goods were not delivered as defined on the invoice, or inadequate supporting documentation requiring investigation by additional clerical effort, not only pushes up the overhead costs of doing business but appears to have a disproportionate effect on customer satisfaction rating.

In a manufacturing company, the subject of effectiveness and efficiency, having a direct correlation with costs and margins, are paramount and this is increasingly so as competition becomes ever more fierce. Referring to the AMR Research REPAC model [3], to be effective, the business needs to execute the plan – the worst case scenario being to manufacture the wrong amount of the wrong product at the wrong time. To be efficient demands control of the overall manufacturing process, including preparation activities such as material staging, in order to minimise waste and downtime, maximise yield and eliminate unnecessary overhead costs by automating labour intensive manual tasks.

![Figure 2 – The AMR Research REPAC Model](image)

### 2.2 Integration vs. Manual Data Entry

Having established the need to share information between the ERP and the shop-floor, what are the benefits of automating the information flows? Clerical resource could provide the ERP information to the plant and gather production data for remote entry into the ERP. Alternatively, ERP terminals could be provided on the shop-floor. Integrating the systems by automating the flow of information ensures:
• The information is accurate rather than being subject to typographical errors in manual data entry.
• “One set of numbers”. Production quantities reported by the shop-floor are consistent with the figures to be used by logistics, finance etc. because the potential for misinterpretation is removed.
• Confidence in the accuracy of the ERP information grows, facilitating additional analyses to identify opportunities for improving business performance.
• More timely update of information, improving the potential responsiveness of the business.
• Increased resolution of business control through more frequent exchange of information.

Using additional separate clerical resource to manually transfer the data adds additional cost whilst putting R/3 client PCs on the shop-floor may be inappropriate for reasons including the following:

• Adds hardware, infrastructure, software licence and ongoing maintenance cost because additional client PCs are required.
• Style of user interface may be inappropriate.
  o Typical plant-floor systems have very simple user interfaces – for example, navigation between displays may be by pre-configured buttons on a graphic display. Navigation between R/3 transactions may require use of several pull-down menus or entry of a 4-character transaction code. This may therefore require a significant re-training commitment and further increases the risk of inaccurate or late data entry.
  o The plant environment may impose additional constraints on operator workstations, such as requirements for water or explosion protection. It is difficult to imagine operating the R/3 user interface via a touch screen, for example.
• Particularly where material movements and allocations are concerned, for example following rejection of a container of an ingredient, R/3 may need several transactions to be executed in the correct order. An integrated system can implement the necessary logic, reducing the risk of errors or delays and saving operator time and aggravation.
3. Typical Information Flows

The diagram shows typical information flow in an integration of a SAP R/3 production planning module with a manufacturing system. Information downloaded falls into two categories: details of what is to be made and the information to be returned to R/3 as the batch is made and completed. Typical information uploaded to R/3 consists of actuals from production.
So how does such a relatively simple set of information flows help the business meet its objectives? The following table shows some examples:

<table>
<thead>
<tr>
<th>Objective - category</th>
<th>Objective – detail</th>
<th>How achieved</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Supply chain</strong></td>
<td>Capability to Promise (CTP)</td>
<td>R/3 has knowledge of demand on the plant and accurate knowledge of inventory (raw materials and finished goods).</td>
</tr>
<tr>
<td></td>
<td>On time in full (OTIF)</td>
<td>No delay in advising plant of need to produce. Correct amount of correct product will be produced. R/3 will know when product is available for dispatch.</td>
</tr>
<tr>
<td></td>
<td>Traceability</td>
<td>R/3 knows which ingredients went into which batch. Without these information flows, the information may be fragmented across disparate systems so analyses would, at best, require more effort and a longer elapsed time.</td>
</tr>
<tr>
<td></td>
<td>Invoicing accuracy</td>
<td>Benefits of an ERP – an integrated suite of functionality covering financials, sales etc. Once accurate production data has been uploaded to R/3, dispatch and invoicing will be based on accurate data.</td>
</tr>
<tr>
<td></td>
<td>Ability to share information across the supply chain</td>
<td>Stock levels in ERP will be accurate. From the perspective of eBusiness and supply chain management, the ERP needs to have accurate stock levels.</td>
</tr>
<tr>
<td></td>
<td>Availability to despatch</td>
<td>Quality attribute can be used to block/enable shipment of product.</td>
</tr>
<tr>
<td><strong>Operational effectiveness</strong></td>
<td>Lower inventory</td>
<td>Accurate and up-to-date stock levels in ERP will eliminate the need to hold unnecessary levels of safety stock to take account of possible usage following infrequent stock reconciliation.</td>
</tr>
<tr>
<td></td>
<td>Waste</td>
<td>Prevent errors due to plant producing wrong product or over-producing correct product. Greater accountability for usage of stock. Prevent expiry of raw materials, such as defrosted ingredients in the food industry.</td>
</tr>
<tr>
<td></td>
<td>Redeploy employees</td>
<td>No need for personnel to be dedicated to manual data entry.</td>
</tr>
<tr>
<td></td>
<td>Accurate batch costing</td>
<td>Cost of raw materials used can be calculated. Using phase start and end times uploaded with pre-set cost rates enables activity based costing to generate accurate cost per batch.</td>
</tr>
<tr>
<td></td>
<td>Key Performance Indicators (KPIs)</td>
<td>R/3 has the information from the shop-floor for calculating KPIs such as manufacturing velocity, cost per batch, etc.</td>
</tr>
</tbody>
</table>
4. An Approach to SAP R/3 to Shop-Floor Integration Projects

An integration project must be driven by business need rather than technological capability. Failure to observe this rule will lead to a project that is more costly and takes longer to implement than necessary, reducing the return on investment. The additional coupling between systems may also add to the associated maintenance and upgrade costs. An appropriate architecture will be capable of starting with a limited set of information flows and expanding as the benefits of additional information flows are recognized.

It follows, therefore, that the first step is to identify and quantify the need. This may be in the context of preparing for an eBusiness or supply chain assessment, as part of a factory-level initiative to secure existing benefits or identify new benefit opportunities, or to benchmark performance using KPIs against which improvement targets are set. We have found that relatively short, focused exercises consisting of a mixture of interviews and structured workshops can help manufacturing companies identify areas of significant potential benefit and reveal high-risk weaknesses that may be easily rectified. Supplementing creative thinking with checklists of known benefit areas, such as those identified by MESA [4], help to rapidly target the sessions at promising areas of opportunity.

When addressing IT changes, systems planning is needed to ensure the outcome is an optimum overall architecture. The typical manufacturing software product, whether ERP or SCADA or somewhere between, tends to be highly configurable with built-in structures and software modules to support particular functionality. Consequently, although many products may be capable of implementing a given requirement, implementing that requirement in each product wastes elapsed time, effort and may lead to subsequent operational issues reconciling the data. Having determined the optimum target architecture, incremental developments ensure quick wins with local objectives being satisfied whilst still evolving towards the goal of integrated manufacturing.

The systems planning activity requires a co-coordinated integration team involving central IS and local factory IT personnel, which is often not as easy as it sounds. It is not uncommon for these groups to have different cultures and to be working to different agendas. One approach to this challenge is to establish an integration team including individuals from each group and co-coordinated by an independent organization with factory IT and ERP experience and a track record of integrating them.

![Figure 4 – A Systems Planning Framework](image)

The diagram shows a framework that encompasses the assessment of an optimum architecture, evaluation of the most appropriate R/3 modules to satisfy the ERP requirements and the formulation of a development plan, including the consideration of IT infrastructure requirements. This approach builds on the S95 standard for enterprise to control system integration and, where the manufacturing process is batch oriented, the S88 standards for batch control.
5. **Key Learning From Recent Integration Projects**

This section considers two recent integration projects, one of which integrated with the SAP R/3 PP-PI module and the other with the PP-REP (repetitive manufacturing) module. Key issues which arose are described along with the manner in which they were solved and the learning to be derived.

5.1 **Integration with PP-PI**

5.1.1 **Introduction**

Many companies are in the process of implementing a full logistics solution for their business. This solution encompasses “horizontal” integration across the traditional supply chain processes such as distribution, transport, materials and production planning. It also demands further “vertical” integration of IT systems and business processes in order to close the full supply chain planning and execution cycle.

The goal of this section is to describe the components of a PP-PI implementation in a functional manner. Crucial to the completeness of the functional specification is a complete and accurate definition of the interfaces with its environment.

5.1.2 **Physical structure of a complete integrated system, its components and its interfaces**

![Figure 5 – System Architecture Including SAP R/3 PP-PI Module](image)

The manufacturing execution system (MES) in total is a system layer that fits between the business environment (SAP R/3) and the process environment. The system is responsible for providing the coordination between the business planning done in R/3, and the processing capabilities of a particular plant. The MES converts production information (received from R/3 via middleware), containing the scheduling information together with the recipe (specification of what kind of finished product must be produced, how, how much and under what conditions), into control recipes. These control recipes are then executed in the order defined by the schedule to the MES. The MES uploads process status
information (process messages). The main function of the middleware is to provide an interface between the R/3 system and the MES system.

Before integrating R/3 with the plant floor, the following points should be considered:

- Create a flow model for batch production automation to serve as the framework for the implementation and provide training for vendors.
- Use an integration consultant to map out the different flows and messages.
- Use configurable middleware in preference to writing custom software.
- Use middleware that is certified by SAP. (Perform a literature survey)
  - What functions are currently provided and to what extent?
  - What functions are not provided?
  - What functions are to be provided?
  - Future development plans?
- Secure network communication between R/3 and process computers (alternatives).
- Different time zone between R/3 and process computers.
- No change of release of R/3 during the project.
- Establish strong key user dedication during the project.
- Avoid customized R/3 functionality wherever possible.
- Focus on fundamentals and core functionality.
- Keep the solution “light and simple”.
- Consider no “nice-to-haves” in phase one.
- Keep the expectations focused.

5.1.3 Interfaces with MES

5.1.3.1 The MES to middleware interface

The R/3 system is the central information system from which all activities are initiated and coordinated. Orders received from sales are transferred to process orders. R/3 downloads production information into control recipes in the MES and receives production status information. Communication between R/3 and middleware is implemented by means of a PI-PCS interface that contains the so-called RFC (remote function call) calls. The RFC calls are part of the standard R/3 interface.

The information exchange between the R/3 and MES systems can be divided into 3 broad types:

Base Parameters

Data passed from R/3 to MES for informational purposes only.

Note:

1. For most of the parameters it is necessary to program additional ABAP (advanced business application programming) code in R/3.
2. Material description inside R/3 is 40 characters long. The PI-PCS interface characteristic PPPI_MATERIAL_DESCRIPTION is 30 characters long.
3. Use automatic message generation inside R/3.
4. R/3 recipes versus “generic” recipes inside MES systems.
**Production data values**

This is production data passed from MES to R/3. It was noted that although some data are necessarily passed to support R/3 business processes, a large proportion of the flow is base production data. The latter is not specifically required by the R/3 system and is passed to support manufacturing reporting needs.

**Control data values**

This is control data passed from MES to R/3 to update R/3 status information.

5.1.3.2 The MES to PLC interface

The process control system directly controls the production line(s). The MES is provided with a set of drivers for passing on the required information to the PLCs. The MES inspects certain events on a regular basis in order to detect certain events. After detecting an event, the MES accesses the database variables for retrieving the associated information.

Note:

Plant maintenance information, such as machine starts and running hours, are captured in R/3 for preventive maintenance, having being logged at a local level in the PLC memory.

5.1.3.3 The MES to shop-floor operator interface

The shop-floor SCADA system provides a menu-controlled interface for performing the following operations on the MES:

- starting
- stopping
- monitoring
- aborting
- terminating
- discarding
- processing
- error inspection
- etc.

Additional screens can be easily implemented to satisfy other requirements for communication between the SCADA and the MES.

5.1.3.4 The MES to emergency operator interface

In order to assure continuity of production, an emergency interface is provided which contains functionality to replace the R/3 system in case of malfunctioning. The interface provides the operator with a number of screens in which the operator may enter recipe/scheduling/production information.
5.2 Integration with PP

5.2.1 Introduction

The repetitive manufacturing solution is used in production environments characterized by:

- Products produced on a line often remaining unchanged over a long time.
- Product not manufactured in individual lots. In contrast, a total quantity is produced over a certain period at a certain rate per part-period.
- Constant flow of the product through the production lines.
- Allocation of material consumption (and labour) against planned quantities, not actual quantities.

A company with a repetitive manufacturing process recognized that the manual data gathering and data entry process associated with the operation of the SAP R/3 PP-REP module, was extremely time-consuming, requiring hours of work from shop-floor personnel. This manual process also introduced data inaccuracy and incorrect inputs became the reason for discrepancies in the stock of finished products and components. A mechanism to automatically report materials and activities was desired.

An additional requirement was to make the production plan available to the shop-floor to help improve performance of the plant against a key performance indicator - conformance to plan.

5.2.2 Technical solution

In order to implement the desired change, a shop-floor system was designed and integrated with R/3 through a bi-directional flexible interface. The architecture of this system includes a dedicated database, storing real-time data retrieved through shop-floor equipment. The production plan, produced by the R/3 system, is also stored in this database, to be distributed to equipment around the factory. Scheduling and network monitoring tools complement the implemented solution.

While there is no standard software in the market to satisfy all of the needs, the advantages of using such systems include lower implementation costs, tested and mature solutions, etc. The technical solution was to develop the shop-floor system using packaged SCADA functionality, use a standard R/3 interface mechanism (the R/3 PP-PDC interface, for repetitive environment), and use a commercially available relational database to interface the two and buffer data.

It was anticipated that use of a standard interface solution would minimize implementation time, as no programming effort in R/3 would be necessary, although this premise turned out to be incorrect. However, template code for the interface software running on the shop-floor system was created automatically by R/3, providing some productivity gains.
The remaining sections of this text focus on the R/3 component and the interface between R/3 and the shop-floor system.

5.2.3 Implemented solution

The implemented interface solution was split into two modules - one installed in R/3, the other on the shop-floor server. The R/3 interface was written in R/3’s ABAP (advanced business application programming) code and the shop-floor system interface written in C++.

![System Architecture Including SAP R/3 PP Module](image)

In addition to exporting master data, the R/3 interface is also responsible for exporting the production plan to the shop-floor system, and for posting production data received from the shop-floor system, such as quantities of finished goods produced.

The shop-floor system interface exports information relevant to the reporting of finished, semi-finished and waste production, as well as the reporting of production line run-time. This information is originally stored in the shop-floor system database, populated with data from the shop-floor equipment.

5.2.4 Implementation challenges

In addition to project challenges, a number of technical challenges arose during the project, including:

- Whilst the R/3 documentation suggested that the PP-PDC interface would support a range of functionality, in practice, for our purposes, the interface functionality was incomplete. For example, when reporting activities, there is no mechanism for specifying the type of activity, as required by R/3. This required modifications to the standard R/3 code.
- A complete interface recovery mechanism had to be implemented, to ensure that data would be posted exactly once. This mechanism handles all network, shop-floor system and R/3 server failure situations.
- Extra modifications to the R/3 interface module were required, as consumed components (while reporting finished goods production) were calculated incorrectly by the standard R/3 code. This modification also led to further coding, handling new erroneous situations.
6. Conclusions

The rapidly changing business environment is leading to manufacturing companies pursuing business strategies including supply chain optimization, eBusiness and operational excellence. To be successful, these initiatives require a coherent IT architecture and one element of this is the need to integrate the ERP with the shop-floor. Although many of the benefits and issues apply whichever type of ERP is involved, this paper has referred to integration with SAP R/3 for its examples.

Successful integration of SAP R/3 and MES requires far more than solving the connectivity problem. Underlying technology, such as Microsoft DNA, coupled with standard R/3 interfaces and a middleware software product, enables the systems to communicate. However, in our experience, a successful integration project needs to be business-driven and must address softer issues, potentially including an independent team with full shop-floor to ERP expertise in order to maximize the contribution of different groups within the company. A well-justified business case and development roadmap are key to successful implementation and ongoing exploitation of the integrated system.

Typical R/3 modules involved in shop-floor integration include the PP (production planning) module and its sub-module PP-PI (production planning for the process industries). Communication with these modules can be implemented via standard R/3 interfaces, although some customization may be required within R/3 to support the necessary information flow. Several middleware software products support the PP-PI module’s PI-PCS interface, removing the need for bespoke software to drive the interface and offering additional benefits such as information integrity, decoupling of systems and ease of reconfiguration.

Having successfully piloted such integration, manufacturing companies typically move into a rapid rollout to exploit the benefits and distance themselves further from their competition.

7. References

3 Do We Need A New Model For Plant Systems? The Report On Manufacturing. October 1998. AMR Research Inc.