Control and Automation
Maturity Models in Brewing

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ABSTRACT
How do we choose the correct level of automation for a specific process area within the production facility? How does that facility drive a migration of its control systems to meet increasing business requirements while taking into account very real constraints around skills levels, existing equipment configuration and materials availability?

These are very real questions confronting all of us today irrespective of how basic or advanced our manufacturing facilities are. This paper will present the concept of simple maturity models with regard to manufacturing control systems. It will illustrate the use of the concept through the typical stages of brewing control system complexity found within a brewing process area – from the completely manual to the fully automated configurations. It will further explore the typical business drivers which would require the move from one level to the next as well as the impacted factors to be addressed when driving a migration of the control system. Relevant international standards like S95 and S88 will also be put into context as helpful models and terminology in support of the business needs of SABMiller.
1 Summary

This paper demonstrates the usefulness of the S95 and S88 models and terminology as a “common and objective language” to drive strategic decisions from a corporate perspective down to the level of individual resource capabilities that comprise the total Process Segment capability.

The Capability Maturity Model described here supports a structured review of corporate and site strategies regarding manufacturing capability. A methodology is described to identify changes required for these capabilities to meet changing business requirements and to pro-actively formulate migration plans.

When the core S95 production functions are viewed as workflow procedures within each Process Segment, it is obvious that the quality of products and services delivered by the Process Segment are directly affected by the level of maturity and quality of the complementary set of resources available to the workflow procedure.

2 SABMiller Business Context

SABMiller plc is one of the largest brewers by volume in the world. It has a brewing presence in over 40 countries across 4 continents.

SABMiller had 121 breweries around the world (including 32 sorghum breweries in Africa) during the financial year of 2003 to 2004. The South African Breweries Ltd. (SAB) has 7 lager breweries in South Africa.

Due to the nature of the aggressive SABMiller expansion and brewery acquisitions in many countries, our manufacturing facilities present a large variation in Manufacturing Systems maturity. This variation is even evident in our seven local breweries in South Africa as these were also built over several decades using the best practices relevant at that particular time.

This inherent diversity in the character of manufacturing facilities is a fact of life in the modern globalization era for many industries.

Diversity is evident in several factors affecting the current and future effectiveness of Process Segment capability to meet the improvement challenges:

- Process equipment capability
- Control systems capability
- Material capability
- Utilities capability
- Personnel capability
- Levels of automation
- Expertise and certified competence of the operational team
- Vast differences in cultures and languages
- Different standards and versions of standards
- Maturity of the information systems technology
- Appropriateness of the information network

Process Segment Capability includes both the nominal design capability of all resources as well as the dynamic actual capacity of these resources to deliver the
required level and quality of services at a critical time. Effective scheduling (Capability to Promise) demands a high level of confidence in the predictability of the resources within a dynamically changing environment at various scheduled times of production.

In a scenario where the facilities that manufacture similar products are globally distributed, a well structured and consistent corporate view of the current and required capabilities is essential to enable strategic planning, budgeting and manufacturing performance reporting at a corporate level.

For the purpose of illustrating the principles of manufacturing capability assessment, a scenario of changing market demands will be used as a business driver.

Demands for process improvement are an unavoidable challenge as a result of the consolidation of many international entities into a corporate environment. A highly competitive business environment necessitates improved responsiveness to customer demands.

3 Market demands
Market demands are consumer driven. This has a direct business impact by requiring higher complexity in brand/pack mix and agility to satisfy this fast-changing demand.

![Market demands: Consumer driven](image)

Business impact: Higher complexity in brand/pack mix

Need improved Manufacturing Systems capability to manage process complexity

To meet the consumer demand, Manufacturing Systems will have to improve their capability to manage and control the extended process complexity.

A critical requirement is the need for real-time manufacturing performance visibility and decision support relevant to support human or computerized intervention for optimization of production efficiency and product quality. Enhanced Manufacturing Information Systems (MIS) are thus required.
Real-time process control must have the agility to dynamically modify critical production operations during process set-up or while the process is executing. Enhanced Manufacturing Execution Systems (MES) are required.

4 Overview of procedure

The current large variation in Manufacturing Systems maturity encountered at various plants poses a major question of where, how, when and how much to invest in upgrades. SAB has decided to qualify the current Manufacturing Systems at selected sites to show the baseline capabilities.

Customer needs drive increasing process complexity and responsiveness into the manufacturing capability requirements. Strategic business drivers are thus defined in terms of customer demands and corporate marketing drives.

Increasingly more stringent and complex production process needs drive the level of required Manufacturing Systems maturity to deliver specific outputs. These outputs may be defined at a Process Segment level as Key Performance Indicators (KPI’s). Measurements of these KPI’s may be “rolled up” via business rules for KPI aggregation to support the strategic business drivers.

A Capability Maturity migration path is generated for cases where the current capability can not meet the future demands within an agreed period. Results may indicate that the Process Segment is capable to support the additional requirements. Preventing wastage of budget and project resources for unnecessary capital plant improvement is a direct cost saving if there was a serious intent to do the upgrade without a proper business case.

As with all upgrade projects, you also have to consider the impact on available resources. We need to balance Total Lifecycle Cost and additional process complexity versus real business benefit delivered by the proposed changes.
This leads to a modified proposal for the migration path to reach the target level of maturity aligned to the business requirements.

5 Keep the discussion relevant
The corporate consultant embarking on such a fact-finding mission regarding manufacturing capabilities must talk the language of the local manufacturing operations team. Don’t talk about specific software applications or other information technology issues – focus on understanding the business process imperatives.

Define a common vision and manufacturing system capabilities using a Maturity Model – use “real things” in terms of manufacturing facilities.

SAB has chosen to reflect a minimum of four levels of maturity of each Process Segment as the rows in a matrix of the Capability Maturity Model:

1. Developing capabilities  
2. Established processes  
3. Consistently repeatable processes  
4. Leading best practices

Within each row, further distinctions may be defined to reflect a finer granularity on certain aspects if desired.

When the discussion stays focused at the level of understanding and relevance to the end user, consensus is reached very quickly. Only looking at individual well defined generic manufacturing functions and their interfaces reduces the clutter and drives direct personal responsibilities during the assessment procedure.

Active participation of the local manufacturing team in this capability assessment procedure is required. Firm local ownership of the action plans is the key to the implementation and sustainability of this exercise. It is also important not to create unrealistic expectations of imminent upgrades before the plans had been approved.

6 Strategic alignment: S88 and S95
To help achieve a common view of the current and future state of manufacturing capabilities, the South African Breweries had embraced the ISA-S95 initiative as a reference model and terminology. This follows on the successful implementation at several SAB facilities of batch control projects using the S88 modeling principles and terminology.

The recent S95 Part 3 focus on a clearer understanding of the activities and relationships between activities within the MES layer helped to gain acceptance at SAB facilities to use the S95 model as a reference.

As with most large corporate entities, SAB also has departments with specialized skill-sets in Information Technology, while the focus of the Control and Automation department is different. To enhance the effectiveness of project implementations and create clear focus on specific responsibilities, SAB has chosen to allocate S95 functions that directly drive manufacturing to the Control and Automation group under the Manufacturing Execution Systems (MES) umbrella.
Where the emphasis is more on pure information that supports the manufacturing systems, the functions had been allocated to the Manufacturing Information Systems (MIS) team.

Although each team is performs a specific role, the teams interact very closely and ensure that customer-focused goals are well defined and understood by all concerned and affected parties.
7 MES/MIS Maturity Model for S95 Production Operations

Models were created for both batch process type of Process Segments as well as discrete process type packaging lines. These models provide a common understanding and guidelines to interpret the actual status realistically and consistently.

It is essential that these models should be generic enough to accommodate various configurations and equipment installed by all vendors. However, the models must enable discussions about very concrete things to make quick progress. Examples are used to set the general theme of capability expected at each level in the model.

The highest level uses more sophisticated examples to illustrate some international best practices. At the “Leading, best practices” level of maturity (L1), the quality of MES functions are expected to be of the Six Sigma order of consistency in production to serve as industry benchmarks. The Process Segment capability must be very fast and effective in adapting to product changes and may use relatively sophisticated real-time Statistical Process Control strategies. It must be effectively balanced between the automated and manual portions of the workflow procedures. To deliver cost-effective production, it would be normal to expect architectures constructed of highly configurable components. Adherence to modern international and corporate standards would be a tell-tale feature of advanced maturity.

The first level (L1) reflects a very low level of control technology and islands of automation in the Process Segment. Information integration to higher levels or upstream and downstream processes is non-existent. The MIS functions of data capturing, process traceability, performance analyses and manufacturing reporting are at best done via clipboards and spreadsheets.
8 Capability Assessment

Breweries consist of hybrid processes, including batch processes for the brewing Process Segments, discrete processes in packaging and continuous processes for various utilities such as steam generation, preparation of refrigerants, purification of carbon dioxide, water treatment and effluent treatment.

Assessments at various breweries were lead by SAB consultants using a defined set of Capability Maturity Models as guidelines. The most effective way to achieve valid capability assessment results is to use a multi-disciplinary team where each member focuses on a particular aspect in his/her area of expertise.

The current manufacturing capability of each Process Segment must be assessed in terms of the complementary Resource categories of Equipment, Personnel, Material and Utilities. As the functions within a Process Segment are interdependent for manufacturing success, the performance of a particular Process Segment will be limited by the level of maturity of its weakest link.

Balance between all functions is required to achieve the maximum level of automation. As dictated by differentiated charter, it is sometimes acceptable that certain production functions are not optimized and that the approach of choosing an appropriate lower level of maturity is more economical.

The following matrix provides an example of some arbitrary descriptions of increasing levels of maturity in manufacturing capability for Production Execution and Performance Analyses functions. The listed factors are not exhaustive but are used to illustrate the principles of classification of levels of maturity.

In general, more mature MIS functions would exhibit better horizontal process collaboration driven by critical manufacturing events. These events would be recorded in such a way as to provide robust traceability of all process parameters in relation to Product Segment Requirement Definitions. Traceability references to measuring standards to certify quality assurance instrumentation would also be easily available.

Special attention is required to ensure the robustness of inter-segment material flow management procedures. Adequate process traceability between upstream and downstream Process Segments is expected in a mature site to enable material mass balance verification.

The advanced MIS also would have structured vertical integration via information aggregation at various levels of granularity. Drill-down between the hierarchical layers of control would expose more detail per parameter or KPI. This information integration represents an explicit and bi-directional semantic messaging model between layers and not just technical data connectivity.

The advanced level of MES would normally be characterized by improved process consistency, excellent product quality and process efficiency. Good results may be achieved via pro-active decision making and corrective intervention in real-time rather than trying to apply reactive control too late.
Agility of the MES to respond quickly to changing production orders for a wide range of product requirements is essential for the Process Segment of the future. These change-overs must be implemented quickly without introducing unacceptable product variability or exorbitant running and maintenance cost.

Walking through the actual Process Segment during actual production and spending quality time with the local operators provide a realistic insight to the problem areas and areas of excellence.

Involve all the relevant personnel in a joint discussion to interpret the findings according to the Maturity Model guidelines. Place the current maturity of manufacturing capability per Process Segment as a baseline.

Identify and agree the gaps in maturity of Resource Capability per Process Segment. Develop high level migration plans for improvement. Ensure local ownership of the Capability Maturity Profile by doing these assessments and plans together with the current process area manager.

9 Apply appropriate Control and Automation system design

“One size fit all” is not a cost-effective model of required maturity in process capability for all facilities. A differentiated charter defines different manufacturing capabilities according to the strategic business drivers and Key Performance Indicators. The solution should then be matched to the business requirements.

The design of the Process Segment must be balanced in all aspects to deliver consistent and efficient manufacturing procedures. The complement of Resources working together must support the manual interactions required from the operational staff. This is a general requirement that applies to all designs.
Re-use of existing class-based component modules as standard configurable building blocks characterize modern MES implementations where the Total Cost of Ownership had been carefully optimized during system design and implementation. Older and less effective engineering design methodologies could not capitalize on the more modern modeling approaches and technical components.

The MES must be sustainable and therefore should only contain a level of technology that can be effectively supported by local resources, either internally or as outsourced packages.

A critical step is to define the appropriate level of maturity per Process Segment to meet requirements of future process complexity introduced by customer demands for a variety of products.

Emphasize that S88 Modeling and Terminology applies to all levels of automation ...... beware of resistance to change for due to ignorance or perceived threat of possible job-losses blamed on automation projects.

Break through the initial perception that “S88 Batch Control only applies to complex, software driven systems”. Although the technical implementation might contain complexity, this detail must be well designed, thoroughly tested and robustly embedded so that it is well hidden from the operational and maintenance personnel. Concepts of object-oriented component design can be implemented by using standard Control Modules in the PLC that are configurable via SCADA or batch control system interfaces under strict security access control. This enables low level control code to be effectively “locked away” from inadvertent changes, while exposing powerful module parameterization features to the appropriate higher level control entities.

Use the objective models and terminology of S88 and S95 to overcome language differences, cultural barriers and vendor misalignment.

Applying effective S88 modeling principles is critical. Installing the latest and greatest software can not compensate for a poorly designed set of Process, Equipment and Procedural models that introduce serious process constraints, introduce unnecessary complexity of operator interfaces or limit control flexibility.

Identify the unbalance (bottleneck) in each Process Segment ..... This is a rough-cut application of the Theory of Constraints (TOC) without delving too much into detail. Identify major constraints contributing to the bottleneck. Ask the operators – they would already know what the major process headaches are.

10 Things that worked for us

We have used S95 models, structures and terminology extensively. Develop a corporate modeling methodology and apply the S88 modeling principles with great care. Ensure correct mapping of these two standards and use their terminology as “the common language”. Using an international standard as reference creates quick buy-in as an objective approach to a process that might step on more than a few sensitive toes.
Understand differentiated Charter needs and required maturity of a particular Site. A formal manufacturing charter provides clear direction and business context for the capability assessment and ensures linkages to the strategic business drivers.

Promote the use of existing corporate Process Flow Diagrams for all sites – guide all sites towards the corporate “point-of-sameness”.

Compile and issue “Starter Kits” of tested Control Modules and basic SCADA configurations – this can deliver a significant jump-start to projects and reduce the risk, cost and time for implementation drastically. Show the benefits of not redeveloping the wheel by referencing success stories at other sites.

Enforce corporate governance of existing standards – this needs firm management drive in a top-down way.

Share practical knowledge, including project methodology, define generic formats for CFS documents, identify critical areas of FAT and commissioning, operations and maintenance experience. Face-to-face forums between well experienced project implementers and newcomers create a sense of urgency through a can-do attitude expressed by champions. Play the “real project movie” from beginning to end to settle unrealistic expectations that “this project will not need much resources, thinking or effort”.

Create a shared knowledge base with easy web-based access via your corporate intranet. Beware of exposing bad practices in a way that will create a negative response – rather emphasize the good things and encourage local ownership to eliminate the bad things identified during the capability assessment.

Apply a consistent project execution methodology – this needs constant attention and well trained project managers. Dedicated and experienced engineers are required.

The crispness and completeness of the Conceptual Function Specification (CFS) and a very thorough Factory Acceptance Testing (FAT) are critical success factors for all manufacturing systems projects, including control and automation systems capability upgrades.

Don’t underestimate the importance of clear ownership of the CFS and FAT by the Process Engineers rather than the Control and Automation department. Control and Automation engineers must be held accountable for the effectiveness of the Detail Design of the process requirements specified in the CFS, initial system testing and technical infrastructure.

Define clear and firm project quality gates at various stages. Spend more time up-front during the definition phase before detail design and implementation begins.

Focus attention to address the weaknesses of the Process Segment and to neutralize problem areas. Measure the actual degree of success of the project in achieving these requirements.

Demonstrate a small, thin slice of the project as early as possible. Involve the local operations staff, maintenance and management.
Do process control simulation, thorough testing, piloting and corrections until no further faults can be identified. Do not install a half-baked system on an active production site – failures and wrong results create a very negative image of a well-intended project. It is a high risk procedure to modify and revalidate a system that is already in use by production. Most inherent faults will stay there.

Match the personnel competence to technology – adequate training for management, project team, operations and maintenance personnel is essential.

Remember - technology makes MES/MIS functions possible, but only people can make it work!

**11 Manufacturing Systems Strategic Drivers**

Some examples of the strategic drivers and factors impacting on the requirements for particular levels in maturity of Manufacturing Systems Capability are shown at the top of the following diagram. The resultant differentiated charters may then lead to specific modifications of the Information Management Strategy, Applications selection strategy and Technical Infrastructure Strategy.

These strategies applicable at a corporate level should be adapted to the requirements of particular Process Segments. A “one-size-fits-all” strategy is less effective in a highly competitive business environment where specialization and complex processing is required to deliver the fast-changing customer requirements.

**12 S95.01 Components of Process Segment Capability**

The interaction between various Resource Capabilities and their effect on the overall Process Segment Capability is evident from this diagram as per the S95 documentation. It illustrates the idea that various categories of resources are available and that they should be matched to the manufacturing requirements.
The level of automation is a result of the trade-off between control system capabilities and manual work to deliver the total workflow requirements. This mix may be different at various sites and this could be acceptable if the quality of products and services is achieved.

**A Process Segment is some collection of material, personnel, and equipment**

13 Required Capability
Define required Capability from a Corporate Business Perspective to achieve a sustainable manufacturing facility. As an example, some of the relevant factors might be weighted for consideration.

- Long term Business Plan for the facility may consider:
  - Geographic distribution of other manufacturing facilities
  - Geographic distribution of local target markets
  - Transport and communications infrastructure
  - Corporate culture & responsibility
  - Socio-economic constraints
  - Competence and constraints of the workforce
  - Availability, competence and depth of local technology partners, systems integrators and support infrastructure
  - Environmental issues
  - External factors
  - Global competitiveness

- Marketing and Sales Forecasts defined strategies for corporate survival and steady growth in a globally competitive arena.
- Differentiated products/services per Site and per Process Segment (scope, range) demanded by customers.
- Current constraints in levels of maturity per Site and Process Segment provide opportunities for improvement.
Evaluate gaps between the actual current Process Segment Capability versus the required capability and derive migration plans – use the Maturity Model to support decisions.

14 Benefits
Some of the actual and envisaged benefits of this approach of using a defined Capability Maturity Model are:

- Common models and terminology.
  - Consistent corporate benchmarking.
  - Consistent manufacturing performance analyses.
  - Knowledge base of site capabilities at a fairly granular level to be used for several types of business decisions.
- Effective supply and delivery grid planning.
- Management understanding of the simple maturity model.
  - Enable long term strategic planning.
  - Awareness and focus on improving bottlenecks.
  - Support for upgrade budget decisions.
- Knowledge sharing of Best Practices.
  - Reusable, interoperable modules.
  - Faster, low risk project implementation.
  - More cost-effective project delivery.
  - Common “look-and-feel” of operator interfaces and maintenance.

15 Essentials
In summary, the following items are essential to the success of adapting manufacturing systems capabilities to compensate for changes in strategic requirements:

- Focus on understanding the strategic Business Processes.
- Leverage existing investments – pick those low-hanging apples before they rot or fall to the ground.
- Identify gaps using a structured Maturity Profile of Capabilities with sufficient levels of granularity to support upgrade decisions.
- Use international benchmark performance criteria of similar process, discrete or continuous types of industries to set appropriate and realistic targets.
- Doing the exact same job with a newer technology seldom provides significant returns on the investment – there has to be a stretch target compared to the current situation.
- Manage the business impact of technical changes:
  - Drive quick, well informed decisions based on facts.
  - Ensure that appropriate solutions are selected by using a structured decision framework.
  - Plan to do effective change management programs.
  - Incorporate a focused human competency development program as part of the improvement plan.
  - Actively drive improvements to embed quick-wins.
16 Conclusions
The Capability Maturity Model provides a tool for management understanding at a strategic level and to define motivated migration plans for required manufacturing systems upgrade strategies.

The S95 diagram for the Production operations management activity model has been used effectively to support a process of quantifying requirements for differentiated levels of maturity per Process Segment in relation to the differentiated production charters and changing demands of the business environment.

17 References:


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ISA Draft 95.00.03 Enterprise - Control System Integration Part 3: Activity Models of Manufacturing Operations Management - Draft 17

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