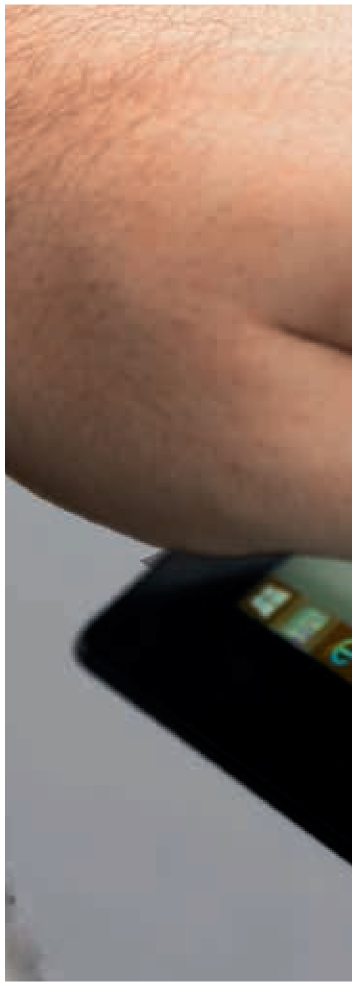
CONTROL AND PRODUCTIVITY

# An easy-to-use and flexible scheduling component



For many, production scheduling is still a complex and exotic functionality that seldom finds its way onto the shop floor. ABB has used the ISA-95 standard as a neutral data-exchange platform upon which to base an easy-to-use and flexible Gantt-chart scheduling technology. This technology is available to businesses in the form of building blocks for industry-specific products.

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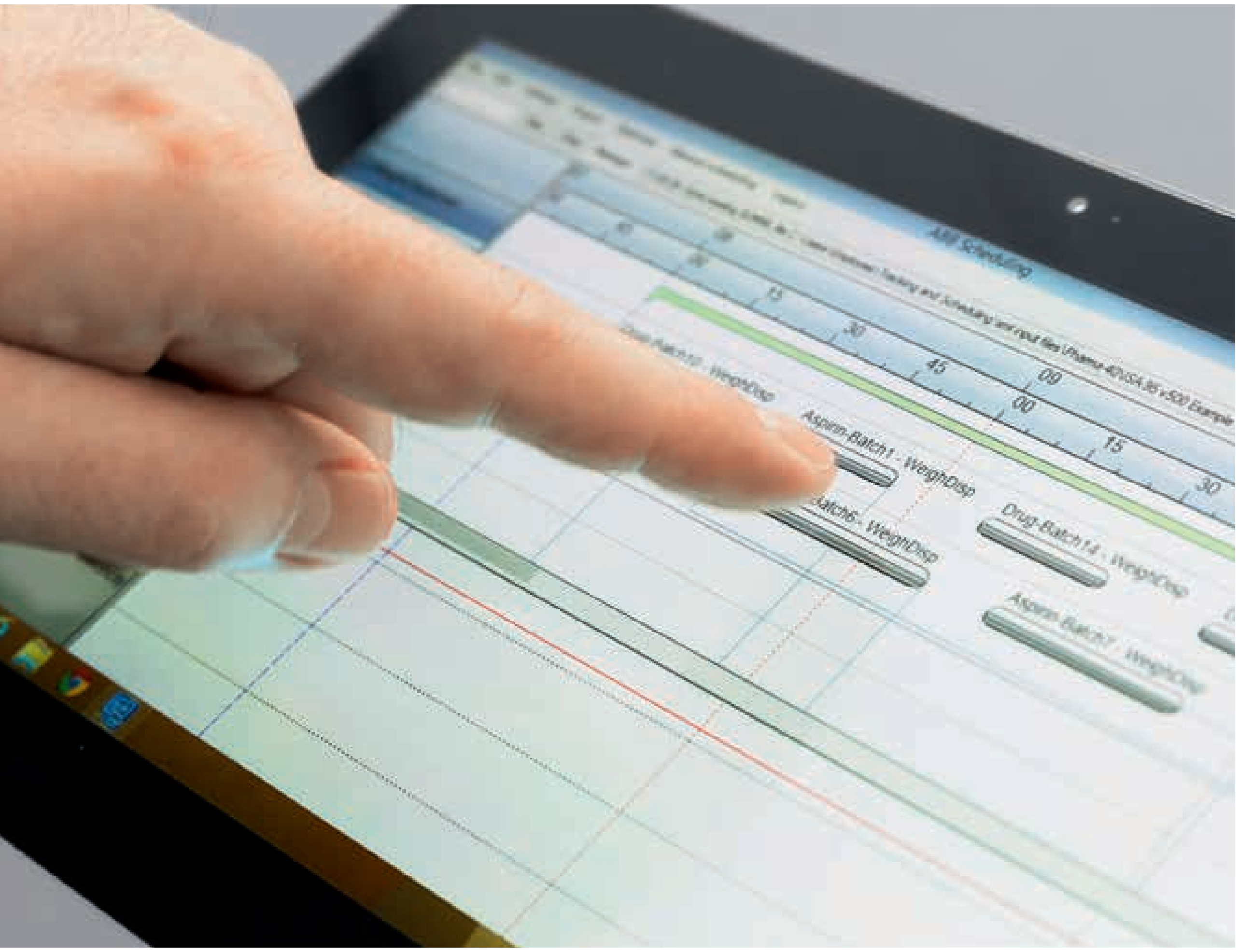
Over the past two decades, there have been many significant achievements in the development of scheduling models, methods and solutions. Nevertheless, an extremely important and still partly unresolved technical challenge remains: How to deploy these solutions efficiently in an industrial context. A common approach is to connect plant experts and process owners with optimization specialists to build a local solution. This approach often results in strongly tailored implementations that are normally not reusable and difficult to maintain due to their complexity. These restrictions inhibit wider distribution and lead to islanded software solutions.

A scheduling solution should be closely connected to the production environment in order to be able to automatically obtain all the production and process data necessary for scheduling.

However, with the ever-increasing availability of data and a higher level of automation and electrification, production scheduling can no longer be seen as an autonomous solution. Concepts such as Internet-of-Things, smart grids, smart manufacturing, Big Data, Industry 4.0 and software-as-a-service (SaaS) as well as heightened emphasis on enterprise-wide optimization topics [1] increase the pressure to connect to and interact with neighboring solutions and systems.

In most industrial environments, a scheduling solution should be closely connected to the production environment – for instance, to a distributed control system (DCS), manufacturing execution system (MES) or collaborative production management (CPM) system – to automatically obtain all the production and process data necessary for scheduling. A connection to the enterprise resource planning (ERP) system is often essential since production is usually triggered by customer orders entered via an ERP interface. ERP systems are also used for procurement to ensure that the appropriate material and resources are available when called for by the production plan.




For successful scheduling, the following must be known:

- Resource availability – equipment, materials, personnel, utilities, etc.
- Dependencies and rules related to the process steps.
- Current state of production and capacity of the production resources to absorb further production demand.
- Production orders with their due dates and priorities.
- A target for the scheduling.

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One of the cornerstones of the scheduling component is the ISA-95 standard, which was created to act as an interface between business and control systems.

Some data may change from minute to minute, which highlights the need for connectivity that ensures the schedule is kept up-to-date. In the approach considered here, most of this dynamic type of information has been modeled using the ISA-95 standard [2], which makes it easy to share and communicate between system components.

**Benefits of scheduling**

It is very important to understand what industrial production companies truly need. In times of hype and trends, the technologies themselves easily become the drivers and in the enthusiasm of embracing them it may be forgotten what the primary needs of a typical customer are. Some of the most sought-after aspects of advanced scheduling solutions are:

- Safety: Scheduling can improve safety by, for instance, providing an overview of future operations or by avoiding complex changeovers or larger simultaneous operations on the plant floor.
- Lower cost and simplified operations: This becomes more critical with increasing process complexity. An operator who uses the solutions should be able to get a better grip of the cost and feel supported by the solution.

- Production efficiency: Throughput maximization and minimization of setup times.
- Better asset utilization (return on assets): It is important to ensure that best use is made of expensive assets. Here, scheduling can help and can even indicate if there are redundant assets.
- More effective decisions: An automation system should primarily help to manage the process and assist in faster and more reliable decision making.

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All input information for a scheduling problem can be provided through B2MML.

In general, a working scheduling solution contributes to a better overview of plant operations and early detection of bottlenecks. It can also improve performance through more balanced machine utilization and higher reliability. Also, automated scheduling can help to adapt to rapidly changing situations and identify high-quality schedules, independent of the operator's skills. The benefits, trends and challenges of practical scheduling deployment projects have been well documented [3].

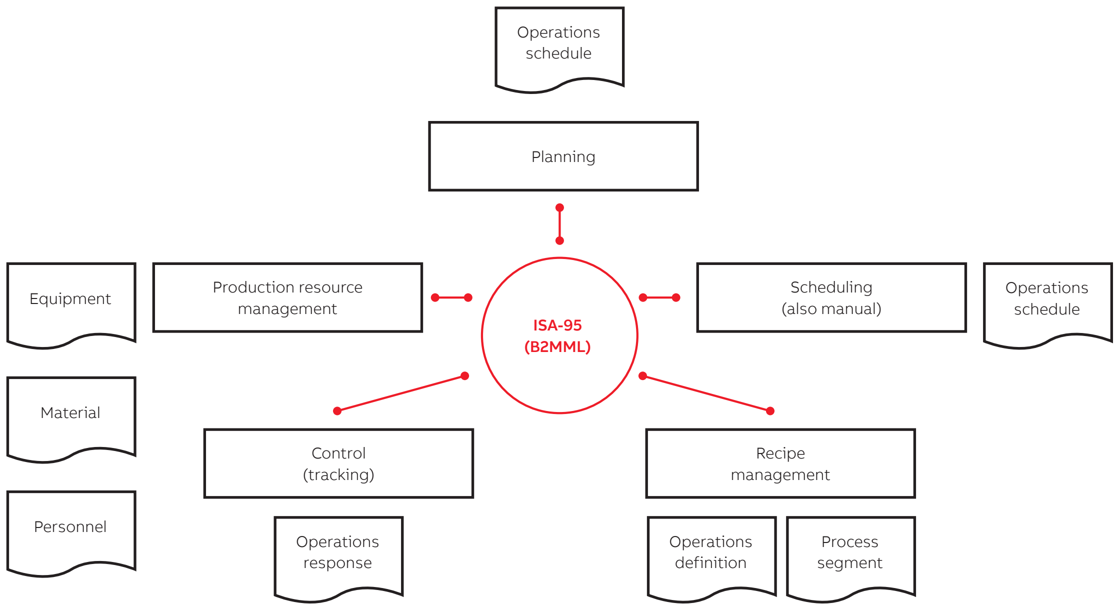
**The scheduling component**

For a successful scheduling solution, it must be ensured that the main challenges that apply to the productization of scheduling solutions can be addressed:

- Define a landscape that can host the algorithmic environment, gather the necessary data and communicate the results to the production process.
- Find a generic problem description that can express realistic problem instances.
- Provide algorithms that work efficiently for various cases and provide good and feasible solutions.
- Maintain the solution through a suitable for non-experts configuration environment.

**Landscape**

One of the cornerstones of the prototype developed by ABB is the ISA-95 standard, which was created to act as an interface between business and control systems. It defines most of the required data fields and offers an XML-based implementation for the integration called B2MML (business to manufacturing markup language) [4]. The standard offers supporting functions such as XML schemas and many programming languages have built-in support to enable easy handling of XML data. All input information for a scheduling problem can be provided through B2MML. Similarly, the scheduling results are provided in the same format. Most common scheduling-related information is directly supported and can be complemented through extensions.

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01 ISA-95 and B2MML elements providing all the information required for scheduling.

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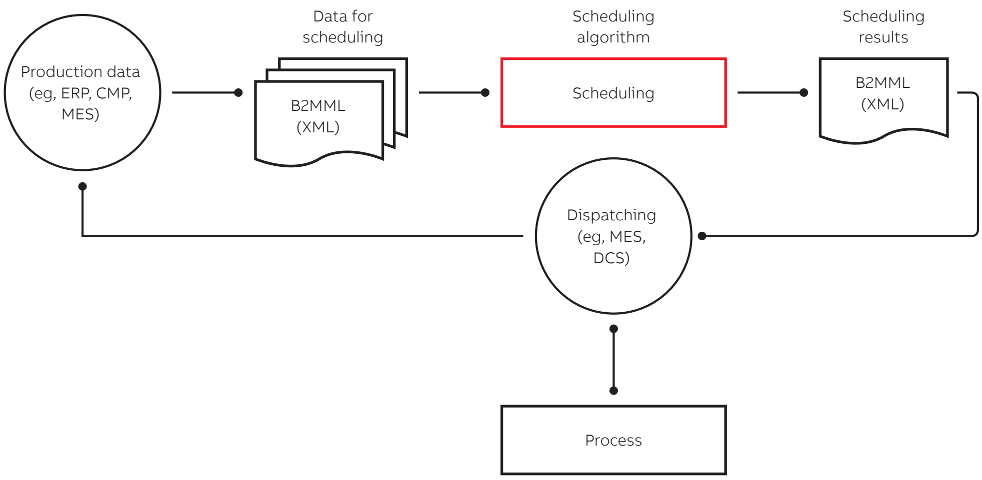
02 Example of a workflow using B2MML data exchange.

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As can be seen in →1, information related to equipment, material, personnel, production recipes and production targets are included in the environment defined by ISA-95. The current production situation is communicated through the operations response data structures. The data is passed to the scheduling algorithm only through XML, which offers the flexibility to integrate the scheduling functionality and allows the use of various types of algorithms as the input data is neutral and usable by any selected solution approach.

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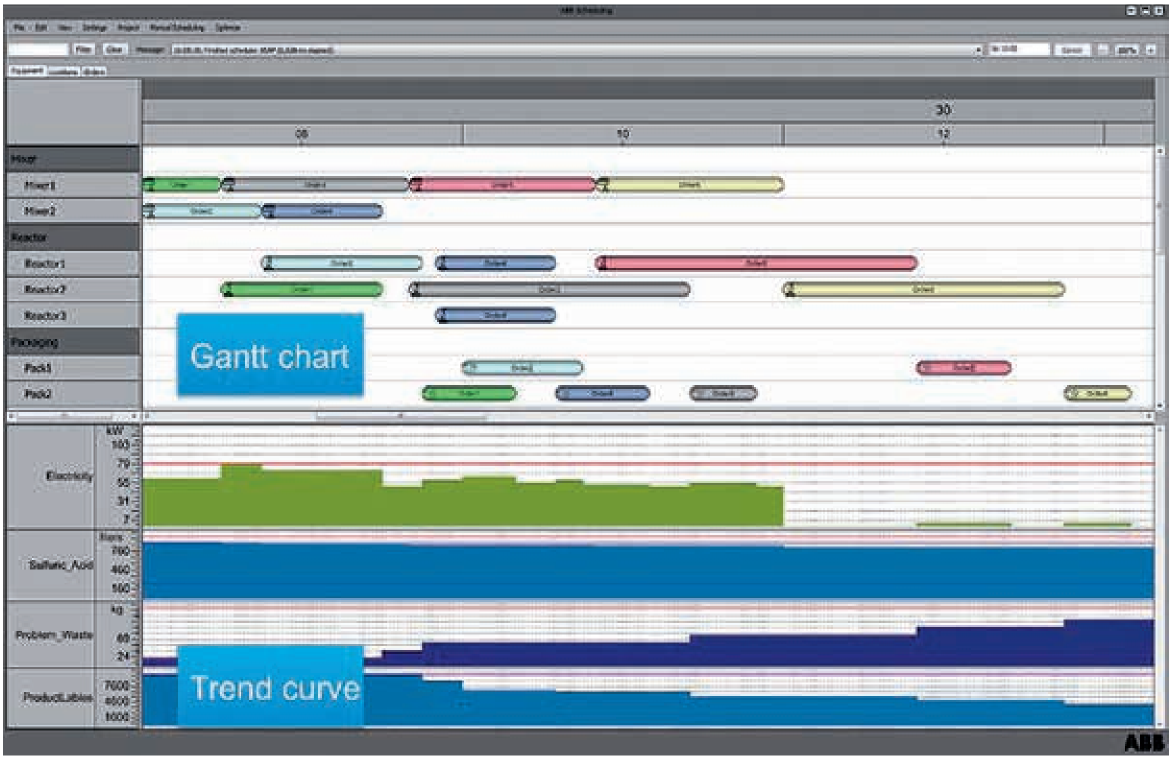
The scheduling tool hosts a set of heuristic algorithms that quickly finds a feasible and good solution.

In →2, an example of the workflow with B2MML is shown. First, the production data (ERP, CPM, etc.) for scheduling is collected from various systems. The data can be acquired by a push or pull principle. After executing the scheduling algorithm, the scheduling results are provided to a dispatching system, which interacts directly with the process. Ideally, the entire ISA-95 dataset can be stored in a common database that is regularly updated by all related software components.

**Algorithms**

The scheduling tool hosts a set of heuristic algorithms – a natural choice since the aim was to provide a fast-responding generic algorithm that does not necessarily reach the global optimum (ie, best possible solution) but quickly finds a feasible and good solution. The algorithm can take into account all major equipment constraints, working hours and standard limitations in energy, material and personnel. Thus, the scheduling system can track the consumption of utilities as well as the use and production of material →3.

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A novel feature of the prototype is its manual drag-and-drop functionality. Due to the fast algorithmic performance, it is possible to combine the automatic algorithm with the manual drag-and-drop functionality.

The scheduling solution can operate in various modes ranging from a purely visual manual tool to a complex algorithmic solver. In the purely manual-driven mode, for instance, the decision logic is left fully to the operator without any repair actions. Orders are moved using the drag-and-drop functionality and a sanity check is performed against the production recipes – if the rules are violated the move is rejected. Alternatively, the manual actions can be supported by algorithms that, for instance, redo the complete schedule or parts thereof based on the manually initiated change. The manual option allows intuitive rule-based actions to be performed that would be too complex to reflect in a generic algorithm.

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The algorithm can take into account all major equipment constraints, working hours and standard limitations in energy, material and personnel.

It is also possible to extend the prototype with additional algorithms, which can be implemented in any .net language.

**Configuration**

Configuration mainly involves the creation of the required B2MML files →4. The use of a standard such as ISA-95 makes it easier to agree on a data model and simplifies communication between systems from different vendors. Maintaining generic data in an ISA-95 database is much easier than collecting proprietary model data. Further, ISA-95 has established itself as the standard of choice for integration between ERP and the manufacturing layer, and ever more professionals are trained in B2MML.

Ideally, the B2MML data would be used to model the scheduling problem in an operator-friendly way – for instance, through tailored GUI elements and using familiar terminology.

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03 The scheduling system showing a typical Gantt chart and the trend curves for tracking electricity and material.

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04 Example of a B2MML file. The text in black reflects the case-specific data; ISA-95 standard tags are shown in red.

### Scheduling the future

The prototype solution has been successfully tested on several example problems in different industrial domains and shows a high benefit potential. It adds to the technology and procedures available to businesses as building blocks for industry-specific products and has already been used in mining. The heuristic approach is scalable and flexible, and,

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**Information related to equipment, material, personnel, production recipes and production targets are included in the environment defined by ISA-95.**

with its fast execution time, the prototype can act as an interactive solution. It provides a straightforward way to model various requirements and can easily be extended to accommodate future needs.

Technical trends are changing the traditional automation pyramid hierarchy in which decisions are taken in an isolated manner. As a consequence, complex systems are becoming simpler to manage. Since scheduling is less worthy in a standalone form, integration is the key to improvement. It is also important to align technology and business properly to ensure meaningful and valuable results. The natural home for a scheduling solution is within a production management system, where the short-term decisions are made and where the necessary process information is available. ●

```
- <OperationsSchedule xmlns="http://www.wbf.org/xml/B2MML-V05">
    <ID>Factory A schedule requests</ID>
    <Description>This example shows the schedule *after* optimization</Description>
    <StartTime>2012-08-30T08:00:00</StartTime>
    <EndTime>2012-08-30T17:30:00</EndTime>
    <ScheduleState>Forecast</ScheduleState>
    <PublishedDate>2012-08-30T07:40:00</PublishedDate>
  - <OperationsRequest>
      <ID>Order1</ID>
      <StartTime>2012-08-30T08:00:00</StartTime>
      <EndTime>2012-08-31T08:00:00</EndTime>
      <Priority>1</Priority>
      <OperationsDefinitionID>Chemical1</OperationsDefinitionID>
    - <SegmentRequirement>
        <ProcessSegmentID>Mix</ProcessSegmentID>
        <EarliestStartTime>2012-08-30T08:00:00</EarliestStartTime>
        <LatestEndTime>2012-08-30T08:30:00</LatestEndTime>
        <Duration>PT0H30M</Duration>
      - <PersonnelRequirement>
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        </EquipmentRequirement>
      - <MaterialRequirement>
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          <MaterialUse>Consumable</MaterialUse>
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          </Quantity>
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    </OperationsRequest>
  - <OperationsRequest>
      <ID>Order2</ID>
      <StartTime>2012-08-30T08:00:00</StartTime>
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**References**


[1] I.E. Grossmann, “Challenges in the application of mathematical programming in the enterprise-wide optimization of process industries,” Theoretical Foundations of Chemical Engineering, 48 (5), pp. 555–573, 2014.

[2] ISA-95: The international standard for the integration of enterprise and control systems, http://www.isa-95.com/

[3] I. Harjunkoski, et al., “Scope for industrial applications of production scheduling models and solution methods,” Computers and Chemical Engineering, 62, pp. 161–193, 2014.

[4] I. Harjunkoski and R. Bauer, “Sharing data for production scheduling using the ISA-95 standard,” Frontiers in Energy Research, 26 October 2014, http://journal.frontiersin.org/article/10.3389/fenrg.2014.00044/full