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NEW GENERATION APS SYSTEMS FOR DEMANDING PLANNING ENVIRONMENTS

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Abstract: The paper examines strategically important management tool - Advanced Planning and Scheduling systems (APS systems) and their efficiency in Demanding Planning Environment. The key characteristics of Demanding Planning Environments are systematized: the uniqueness of the technological processes; high complexity and scope; limited ability to describe and low predictability; high volatility and change sensitivity. The new generation of APS systems is defined. The comparative analysis of the planning systems of several generations (MRP II, APS I, APS II) is provided. Finally, examples of implementations of the new generation APS systems at Trinicke Zelezarny, Czech Republic; TimkenSteel, USA; VSMPO-AVISMA Corporation, Russia are provided.

Keywords: New Generation APS system, Demanding Planning Environment

1. INTRODUCTION

Advanced planning and Scheduling (APS) systems are well known among professionals worldwide [6,8,13,15-17,23]. There are many examples of successful implementations of this type of systems in different industries the result of which was a high business value for the given enterprise [3,13]. At the same time there are also not only few project examples where conventional APS technologies brought less than expected or even fail [7,9,10,13]. The authors of the article introduce an explanation according to which many of these failures are related to objective properties/insufficiencies of the conventional APS systems, which are not able to solve certain problems.

Recent authors' survey introduces specific characteristics of enterprise environments whose presence limits the possibility of efficient deployment of conventional APS systems in specific cases. The more significantly the given enterprise environment is affected by the specified characteristics; the more limited the possibilities for utilization of conventional APS systems for efficient planning. For environments significantly affected by such characteristics, the authors propose using of the term Demanding Planning Environments.

In this article authors analyze conventional APS technologies (let's call them first generation APS) and their deficiency in terms of usability in demanding planning environments. New Generation APS features are analyzed and APS differentiator definition update is proposed. Comparison analysis of planning technologies is provided. In the conclusion practical examples of New Generation APS implementation are overviewed.

2. FIRST GENERATION APS

There are many different definitions of APS systems.

APS is a set of technologies, business processes and performance metrics that enable manufacturing companies to compete more effectively in the global market place. The technologies involved are computer software and hardware that enable organization to change the way they plan, schedule, forecast, distribute, and communicate with customer and suppliers [12].

An APS is a system that suits like an umbrella over the entire chain, thus enabling it to extract real-time information from the chain, with which to calculate a feasible schedule, resulting in a fast, reliable response to the customer [14].

According to APICS Dictionary [2] APS system is defined as: Techniques that deal with analysis and planning of logistics and manufacturing during short, intermediate and long-term time periods. APS system describes any computer program that uses advanced mathematical algorithms and/or logic to perform optimization or simulation on finite capacity scheduling, sourcing, capital planning, resource planning, forecasting, demand management, and others. These techniques simultaneously consider a range of constraints and business rules to provide real-time planning and scheduling, decision support, available-to-promise, and capable-to-promise capabilities. APS often generates and evaluates multiple scenarios.

According to Ivert [11]: "Other terms are also used to describe the same thing creating confusion regarding the concept, e.g. advanced planning and optimization (APO), supply chain planning (SCP) and advanced supply chain collaboration. Besides, many concepts are overlapping each other, and it is difficult to obtain a clear picture about the functionalities and roles of each entity. For instance, the modules of an APS system are often bundled together with the modules of an ERP system and it is not easy to determine which modules that belong to which system. Another explanation for the ambiguousness concerning the definition of APS systems is that software vendors call their solution APS but the functionality of the solution differs between different vendors. The big ERP vendors have successfully achieved an adequate level of functional breadth, which has helped these vendors achieve market-leading positions. A few supply chain specialists have managed to keep pace with the ERP vendors and offer similar functional footprints".

All of these lead to the fact that it is not always easy to gasp the innovative and real aspects of APS systems compared to the previous systems using these definitions. That is why one of the common ways to describe APS systems is to view them in the light of known deficiencies of their predecessors. One of the key differentiator of APS compared to the previous systems looks like:

> *Unlike previous systems (authors' comment: ERP/ MRP II), APS simultaneously plans and schedules production based on available materials, labor and plant capacity [1,4].*

This description has a good grasp on the characteristics of APS systems as they are known. It is important to highlight though that it is possible to see labor force as a capacity as well – so it could be said, that it's planning while simultaneously considering available materials and capacities. Let's also note, that in the sentence above, the word "simultaneously" is mainly related to considering material and capacity and not so much to planning and scheduling.

The abovementioned definition doesn't cover environments where it is not enough to consider only available material and capacity. For example, how about environments, where a significant role is also played by other specific constraints, whether they might be technological or of another nature. The first generation APS technologies are simply blind to them and the more significant the given constraint is, the less valuable the created plan will be (meaning the feasibility and the related benefits will suffer) without taking such constraint into account.

Example: Special steel producers work with hundreds of various steel grades [5,18,19,21], which differ by their chemical composition. The chemical composition of steel is consequently a major constraint for them, with major impact on the planning of the entire material flow, which is significantly affected by the heat plan. If such a company would only consider availability of the material and capacity, the plan would be insufficiently usable as a management material without further finalizing.

Working with specific constraints is not the only weakness of first generation APS systems. Let's now call *demanding planning environments* such environments, where the first generation APS systems did not achieve very convincing results. Leaving the „subjective" aspect of the given case aside (given especially by the readiness of the relevant company for process changes, the quality of a specific APS product, and the abilities of implementation teams of the investor and the supplier), these will be manufacturing environments with the following characteristics:

High uniqueness

Environments, where besides the material availability and/or capacities, a major role is also played by other constrains. These are environments where the requirements on the calculations carried out by an APS system are so unique, that it cannot be reasonably assumed that it would be possible to solve them by parameterizing the planning algorithms the APS system is equipped with and therefore it must be possible to modify the planning algorithms or even create new ones. We thusly identified the first need related to demanding planning environments, which is the need for ability to carry out significant modifications of the planning algorithms and/or to create new, specific algorithms.

Another complication occurs if the nature of the specific constraints requires more than one solver.

High Complexity and Scope

As a consequence of high complexity and scope of the environment, a need may arise to involve more than one planner (and thus for multiuser planning to be supported), especially when it could be hardly assumed that one planner would be able to orchestrate the full complexity and/or scope. This also applies if the planner brings a significant portion of specific information, abilities and know-how into the planning process (which could not be taken into account without this planner).

Limited Ability to describe and Low predictability

The consequence of a limited ability to describe and of low predictability is necessarily increased amount of manual planning. The ability to achieve high automation level is thus limited and the planner's role increases, as does the number of the planning actions he/she performs. A need thus increases for an efficient support of the planner's activities with the emphasis on the customizability, dynamics and the efficiency of the planner's working environment.

High Volatility and Change sensitivity

The result of high volatility and sensitivity to changes will be especially the need for fast replanning. However, fast replanning is conditioned by achieving a fairly high level of detail of the planning model (the ability to include specific constraints of the environment in the model is needed here – see no. 1 above) and a high level of integration of the planning activities. In cases where besides this, a need exists for involving multiple planners, an ability to efficiently manage such team is needed as well.

It seems the more characteristics of demanding planning environments (1 – 4) are bound to the given planning environment, the more limited results can be achieved in the given environment by deploying first generation APS.

The table 1 (2nd column) presents short comments on how the above-stated needs are addressed by conventional APS systems in demanding planning environments.

Table 1. Requirements of demanding planning environments

Need in a demanding planning environment	**How the need is satisfied by conventional APS**
Possibility to perform fairly significant modifications of planning algorithms and / or creation of new specific algorithms	Modification of the algorithms or the development of custom algorithms is usually not possible
Involvement of more than one planning solver in the calculation of a plan / schedule	Such a possibility is not common, usually an APS has one solver that is suitable only for solving certain types of problems (e.g. planning of material and capacity according to their availability)
Effective involvement of multiple planners in planning	If an APS allows multi-user mode, it usually leads to hidden conflicts in planning and thereby reducing the value of the plan
Need for highly customizable and efficient working environment of a planner	Individualization (either for a particular installation, or for a specific planner) is usually limited by parameterization. A substantial modification of tools or even incorporation of additional individual instruments is not usually possible.
Possibility to achieve high level of automation and integration of the planning process	In challenging environments where you can not do with a single planning product, the commonly used one is the concept of construction of planning system of more specialized products for planning and / or scheduling; this concept however greatly limits the achievable level of automation and integration.
Need for highly efficient management of team of planners	Conventional APS simply did not address the support for the management of the team of planners

3. NEW GENERATION APS AND APS DIFFERENTIATOR DEFINITION UPDATE

Let's assume that the world of APS will keep evolving and that APS will remain to be the term used for planning technologies which are now distinguished by their efficiency. However, in order for the term „APS“ to continue to be used for the most powerful planning systems, it won't do without offering more than its first generation predecessors. This has to be manifested in the fact that new generation APS should be able to provide really efficient planning technologies even for demanding planning environments. They should be able to provide technologies that satisfy all the needs (see above Table 1) of demanding planning environments.

Besides that, it seems that the time comes for the generational changes to be reflected in the definition of APS differentiator as well. The following description is proposed:

Unlike first generation of APS, New Generation APS are supporting efficient planning and scheduling of demand fulfillment process, taking into account significant constraints.

The changes comparing with the original description are as follows:

A) **Significant constraints** instead of **available materials and capacity**

Let's start from the end. The original phrase „**plans ... available materials, labor and plant capacity**“ is replaced by „**taking into account significant constraints**“. Although it could be said that material and capacities are constraints present in most manufacturing processes, many enterprises are also burdened by a number of other constraints, while some of them may be so significant, that unless they are taken into account during planning, they can render the resulting plan infeasible.

„Significance“ is in fact a relative term. One cannot define objectively what is significant and what is not. However it is true, that the more perfect the planning result should be, the more complete set of existing constraints has to be considered, from the major to the minor.

B) **Efficient** instead of **simultaneously**

The word simultaneously really is a major characteristic of first generation APS. Still, it illustrates more of the technical side of planning than the value. It assumes, that planning in a way that considers the constrains simultaneously is a guarantee of the best achievable result. Still, the goal is to efficiently create the most valuable plan. And other factors may help besides the way constraints are handled. Ways to more valuable results may, for example, lay in more efficient utilization of information resources, or in stronger what-if support, and so forth. But even if we'd look for an opportunity to improve in the way how constraints are considered, strict adherence to the principle of simultaneous considering of constraints doesn't always have to lead to the best possible result – for example in environments with heterogeneous problems (problems that cannot be solved with simple applying of some of the known modelled methods), better results would be achieved by a solution based on several cooperating solvers and iterations, which also means suppressing the simultaneous constraint considering.

C) **Demand Fulfillment Process** instead of **production**

Although production often dominates the process of satisfying the demand, it is rarely the only factor included. In many enterprises, material needs to be purchased in the interest of fulfilling the order, as do semi-finished products and various components. It is certainly clear that managing purchasing is different from production management, although both of these are closely related. In other companies, a significant role in demand fulfillment may be played by different area. Specifics like these may have a very important role affecting how efficiently the company can satisfy demand.

4. PLANNING TECHNOLOGIES AND THEIR SUFFICIENCY FOR EFFICIENT MANAGEMENT

As mentioned above, deploying first generation APS in some environments resulted in good or event excellent results; in other, however, the results were not so convincing. In this sense, it is very important of how demanding is the given planning environment.

Let's try to make a simple comparison of the value of planning technologies depending on the demands of the given planning environment.

As it was stated above, **demanding planning environments** are characterized by the following attributes: uniqueness, complexity, scope, volatility, change sensitivity, predictability, and ability to describe. Let's also assume, that for the purposes of this article, the 0 coordinate on the planning environment demands axis will be related to an environment, where only capacity and material availability is sufficient to consider to achieve a very realistic planning model (note: the degree of how realistic the model is represents a limitation of the achievable quality of the plan for the given planning system).

Let's now take a look at what we will consider to be a value for management purposes when comparing planning technologies. For our purposes, we propose the value for management purposes to be comprised of the following aspects:

- **Feasibility** of the plan that we can acquire using the given technology

  If the plan can be realized in all its details (regardless how advantageous it is) without any objective facts standing in the way, it is fully feasible. The more details of the plan cannot be realized due to objective reasons (e.g. due to too large capacity overload in some moment in time), the less feasible it is.
- **Advantage** resulting from using the plan

  The degree of how advantageous the plan is relates to how the plan makes use of the objective facts in the given situation in order to meet the goals of the company in the most efficient way (in the given case, the best possible customer service and the best possible operational efficiency).
- **Sufficiency** of the given technology for creating the plan

  Sufficiency increases with the ability to manage with the results acquired using the planning systems without the need to further finalize them outside the system (e.g. manually, using Excel or other additional tools, ...).

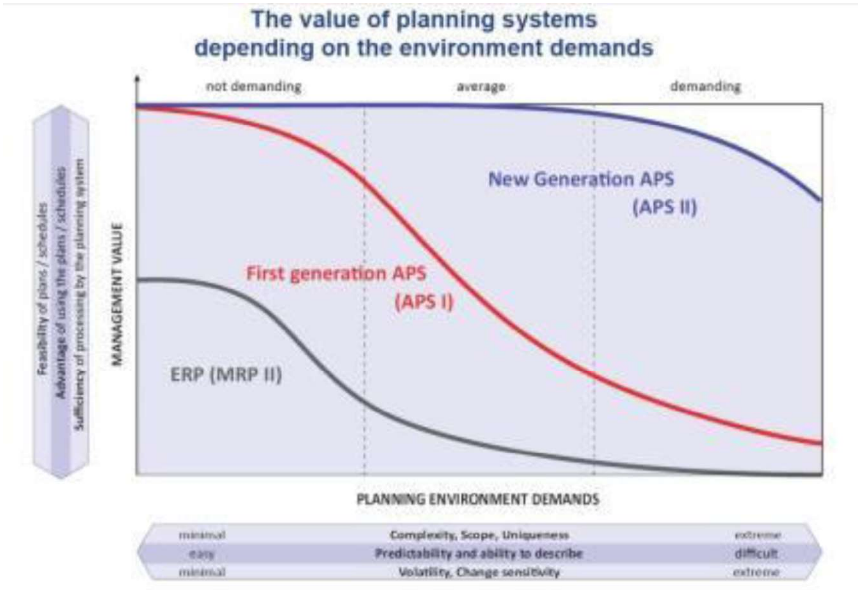


Figure 1. The value of planning systems depending on environment demand

Let's start with the **MRP II** concept (Manufacturing Resource Planning) used practically in every today's ERP system. The value of MRP II is limited by often very low feasibility or by limited advantage resulting from the plan. Consequently, MRP II is sufficient only for an enterprise with a very undemanding planning environment (see Figure 1), which is, in addition, under no noticeable competitive pressure. As soon as the environment complicates even by the simplest thing, the value of MRP II for the purposes of planning decreases rapidly; plans have to be finalized laboriously, in most cases using table calculator tools. Already in planning environments with average complexity, the value of MRP II is very little and speaking of a value of MRP II in really demanding planning environments practically loses any sense.

First generation APS (further also APS I) deals incomparably better with undemanding planning environments. Thanks to its characteristics, in 0 on the planning environment demands axis, it can reach the full management value. As the environment demands increase, meaning as demanding attributes come into effect (uniqueness, and so forth), APS I starts to lose value. This is caused by the fact that APS I is not able to deal with demanding problems – it uses to be blind to unique constraints, insufficient in environments with high complexity and scope and so on (see comparison table, column „How the need uses to be addressed by conventional APS"). The value of APS I thus declines rapidly as we get closer and closer to the really demanding environments – such environments, where the demanding attributes apply strongly or even extremely.

The value of new generation APS (further also APS II) will be very high. Because of the fact that **APS II** is able to consider almost all attributes of demanding planning environment uniqueness, complexity, ...), it will provide the higher value the more other technologies lose in the given environment. Naturally, this will result in only small differences in undemanding environments, but as the environment demands increase, the difference between other technologies, including APS I, will increase significantly. APS II will thus be the only technology able to provide outputs of high value even in demanding planning environments.

Note: Let's note, that the only attribute APS II doesn't satisfy is the insufficient ability to describe. Understandably, that cannot be considered to be a drawback of the given technology. Describing constraints in any environment is something a human must do. And so even practical experience shows that people are not always able to sufficiently describe the rules present in the given environment. It may be difficult to get the needed information in the given enterprise (more people would have to meet that have the needed knowledge but may not even know about each other) or such information simply does not exist yet in the company (the knowledge is insufficient, the given matter is a black box).

But since we are speaking about manufacturing enterprises, we're assuming that the unknown is limited, even in extremely demanding environments – that is also the reason why the blue curve in the diagram does not decline to zero in extremely demanding environments.

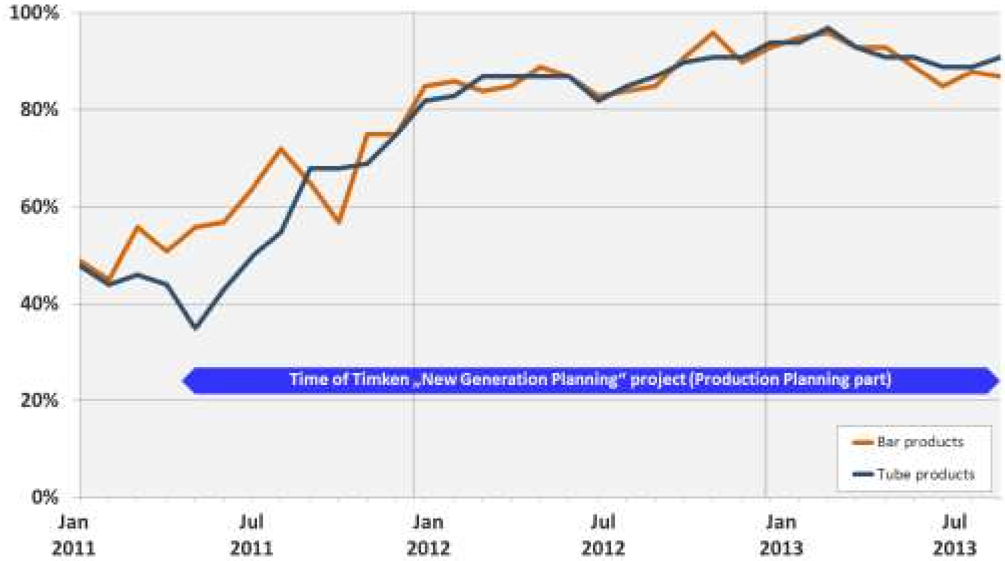
Take into account that this diagram is based on no exact values and is only approximate based on the above described abilities of planning technologies, illustrating the sufficiency of their usage for management purposes. The variables (value for management, planning environment demands) are not exactly measurable and can only be used to compare the lower/higher, more demanding/simpler levels and so on. Let's also note that the specific planning products can provide different value in their categories (MRP II, APS I, APS II).

5. NEW GENERATION APS IN PRACTICE

In recent years, there were number of successful projects of new generation APS implementation in demanding planning environments. There are some of them.

The implementation of elements of New Generation APS at Trinecke Zelezarny [22]. Trinecke Zelezarny is a Czech special steel maker and is one of the leading steel producers in Europe.

The largest deployment of New Generation APS at TimkenSteel [20]. TimkenSteel is an American special steel producer – and undoubtedly operates in a demanding planning environment. In the past, TimkenSteel used to run an A-grade first generation APS. There was a very good opportunity for comparing the two generations of APS technologies (which was even more special thanks to the fact that Timken's team in the project comprised of the same people that used to work with the preceding system). The results are very convincing. The following diagram demonstrates the development of Due Date Delivery Performance after deploying APS II technology.



In 2015 Russian company VSMPO-AVISMA Corporation started a project for New Generation APS[24]. VSMPO-AVISMA Corporation is a is the world's largest titanium producer, having a full production cycle, from raw material processing to finished products with a high degree of machining. The corporation supplies its products to the markets of 50 countries, it is deeply integrated into the global aerospace industry and it is a strategic supplier for many companies.

6. CONCLUSION

It could be supposed that soon new generation APS systems, which cover requirements of demanding planning environments, will take significant share of the SCM market. The main reason for that is that supply chains of contemporary companies keep evolving and becoming more complicated day after day at the same time competition among them is becoming tougher.

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