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Spreadsheet Application still dominates Enterprise Resource Planning and Advanced Planning Systems

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Abstract: Enterprise Resource Planning (ERP) has been a major advancement in production planning and control (PPC), building on material requirements planning (MRP) and manufacturing resource planning (MRP II). To improve planning solutions, advanced planning systems (APS) have been offered since the nineties. Despite these developments and recent developments in digitalization, spreadsheets still play a major role in PPC. This paper describes three cases in which different capacity planning and production scheduling decisions are supported by spreadsheets. This results in a list of issues arising from the use of spreadsheets in PPC. While the advancements in PPC research have been clear over the last twenty years, the cases do not make use of these advancements in practice and we do not foresee that all spreadsheets will be replaced by APS or other digitalization efforts over the years. Therefore, while we focus more research efforts on concepts like digitalization and Industry 4.0, we must not forget that spreadsheet applications still dominates over ERP and APS as the main support for planners in their daily work.

Keywords: Material Requirement Planning (MRP), Enterprise Resource Planning (ERP), Scheduling Heuristics, Decision Support System, Spreadsheet Application, Digitalization

1. INTRODUCTION

In this paper, we address the use of spreadsheets in today's production planning and control (PPC). With spreadsheet application we mean the use of spreadsheets by human planners for the purpose of PPC, i.e. "to make a connection between supply and demand that will ensure the operations processes run effectively and efficiently and produce products and services that are required by customers." (Slack et al., 2010)

Enterprise Resource Planning (ERP) systems are undeniable one of the greatest advancements in PPC, building on the foundations of material requirements planning (MRP) and manufacturing resource planning (MRP II) based systems since the nineties. Digital record keeping in which operational activities update both inventory and accounting information, make ERP systems very valuable to PPC. (Robert Jacobs and Weston, 2007) It is, however, not a customized planning system per se, and the capabilities of provided MRP modules are too limited to provide the planning support that planners need. ERP can provide initial plans, but often do not provide tools that help the planner in analysis and updating the proposed planning. This is supported by an empirical study by Fransoo and Wiers (2008) in which planners largely neglect ERP system proposed production orders, in which the number of manually created production orders increases when planning complexity increases.

Trying to filling the void of limited functionality in ERP solutions, software companies have been pushing advanced production planning software systems and modules (APS) into the market place since the 90s. APS are systems that model the physical problem that needs to be planned, have an engine that can recalculate the consequences of planning actions or changes in state of the modelled problem, and demonstrate the resulting planning in a guided user-interface, demonstrating how resources and materials are used over time (Wiers and de Kok, 2018). APS providers recognize the fact that PPC tasks vary substantially across industries and supply chains. They therefore start to offer different solutions for the same planning task, dependent on the type of industry (Meyr et al., 2015). The success of APS offerings, however, stagnated in the first decade of the century. Large ERP providers took over advanced planning offerings, while they are not specialized and not being dependent on the sales of advanced planning solutions. Because IT departments got their say in IT investments, ERP providers and IT departments often choose for a solution in which transaction and planning management is coordinated, but tools for planning analysis and optimization are missing (Ovacik, 2011).

With a stagnating market for APS, "spreadsheet applications as the primary medium for planning" is one of the major contributors to planning developments in practice, in which planners need to analyse the plans, analyse issues and looks for resolving of problems (Ovacik, 2011). Many have recognized the need for improving existing planning solutions by introducing (improved) spreadsheet solutions throughout the years, see for example Beversluis and Jordan (1995), Chien and Cunningham (2000), de Man et al. (2015). This is contradictive to the late push for digitalization, where

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more advanced and integrated IT systems are seen as the solution for planning and control. (Kagermann et al., 2013)

In our recent case studies, the following has been observed in practice for three different production firms in Norway:

While production records are transacted in ERP systems, the decision of what and when to produce are for each case taken by heuristic and human experience driven decisions that planners process in spreadsheets.

While this might not be the best (e.g. lateness minimization, effective solution generation, good factory utilization, inventory minimization) solution, these cases show that spreadsheets are still a large part of PPC.

This paper explores these three cases that use spreadsheet tools in interaction with ERP systems. We explore why spreadsheet application still plays a large role in today's planning and discuss what the issues are related with this form of planning. Despite the progress in research on planning and control, planning and control in practice is often of a very basic form. The contribution of this paper is to demonstrate why spreadsheets are still widely applied and to what issues this leads.

The remainder of the papers is built up as follows: Section 2 discusses the method of this paper before section 3 discusses the background to the paper. Section 4 discusses three cases using spreadsheet solutions, before reflecting upon the state of planning in section 5. The paper is concluded and discussed in section 6.

2. METHOD

This paper gives the result of an exploratory case study on different instances, exploring why a certain phenomenon, i.e. spreadsheet application, occurs and what issues come forward from this phenomenon. By describing the current use of spreadsheets, we gain key insights and issues that come forward from the cases, for which an exploratory case study can be used (Handfield and Melnyk, 1998). The unit of analysis is the use of spreadsheets and its context in PPC. We have three different cases that have similar use of spreadsheets. These spreadsheets have been analysed through interviews and desk analysis driven by the hypothesis that an analysis of spreadsheet application reveals the issues in today's planning and control. Gaining knowledge from three cases gives a deeper understanding of current spreadsheet applications that leads to a more specific research agenda on PPC, especially on how we must address the difference between practice and the possibilities of further developing PPC. The selection of three cases has been to help guard against observer bias and improve the external validity of our observations. (Voss et al., 2002).

The case companies have characteristics that vary, as denoted in Table 1, by making different products, being of different size and producing to stock or to order. The case descriptions will go into detail for which PPC functions spreadsheets are used.

Table 1. Case characteristics

Case	Product	# of employees	Main production strategy
1	Cheese	+/- 5000	Make-to-stock
2	Confectionary	+/- 250	Make-to-stock
3	Furniture	+/- 1500	Make-to-order

3. BACKGROUND

PPC frameworks (see for example Hax and Meal (1973), Vollmann et al. (1997), Zijm (2000)) structure the different functions and relations between functions in PPC, both in a timing perspective and in the relation between supply, production and demand.

Planning, scheduling and dispatching have different purposes and can be seen as three timing levels in PPC. Planning can be seen as assigning work to buckets in specific periods, while schedulers and dispatchers assign specific tasks to specific resources. Scheduling focuses on the near future, while dispatching is concerned with real-time assignment of tasks to resources. (McKay and Wiers, 2003) In the remainder of this paper, we will refer to these planning functions, and to planners as humans who can fulfil all three functions.

McKay and Wiers (2003) note that planning, scheduling and dispatching are seen as black boxes, i.e. it is unclear how these functions must be carried out in practice. This leads to a situation in which each firm or plant has its own interpretation, performing each function according to its own constraints and experience. This implicates that production planning and control frameworks do not necessarily account for the planning tools and methods that are used in practice.

ERP systems do account for the basic planning functions in most firms, providing initial plans, e.g. if in an ERP's product bill of material (BOM) lead-time and construction logic is set, material requirements planning can result in a reliable set of orders that are sequenced in a logical order. Reasons for not following the planned orders have a wide variety: The planner does not trust the techniques generating the schedule, the planner does not update the parameters of the ERP system that are needed, or the planner has more information than the system. It can also be that the planner has the feeling that an increased mental effort will increase the outcome of the resulting plan or schedule, which is not necessarily true. (Fransoo and Wiers, 2008, Stoop and Wiers, 1996)

In addition, the role of the human planner has been a widely addressed topic. Humans both possess cognitive strengths and weaknesses that influence the quality of planning. But while APS solutions should support, not replace, human planners, the human role is not necessarily well understood. (Stoop and Wiers, 1996, Wiers and de Kok, 2018)

This gives that spreadsheet solutions are part of today's planning, scheduling and dispatching to support human planning tasks: Visualizing planning, making planning and scheduling calculations for orders, and showing dashboards are a range of solutions that we found across spreadsheets in the three cases. The planner constructs these solutions when he assumes that the system in use cannot provide a parameter setting, planning calculation or visualization that improves the planning method a planner is using. Fig. 1 demonstrates this functionality, in which spreadsheet solutions build upon ERP planning output. Spreadsheets cover up the deficiencies of the ERP system, helping the planner in planning orders to a specific time bucket in the future, scheduling orders to specific resources in the near future, and dispatching orders in the present. (Ovacik, 2011)

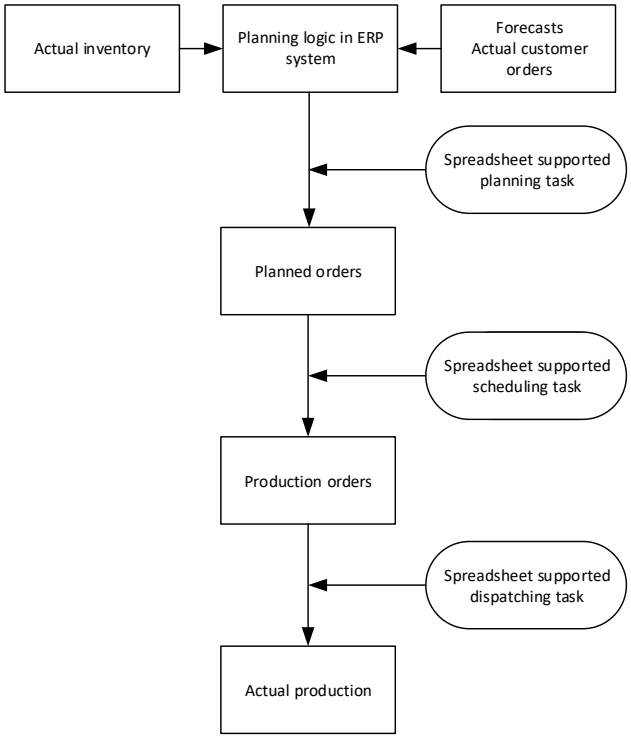

Fig. 1. Spreadsheet support in planning, scheduling and dispactching, based on Fransoo and Wiers (2008)

As this background sketches, spreadsheet solutions provide support to planners in production environments. These tools are not necessarily built to strict guidelines, but the result of production environment developments over the years, often satisfying the direct need of the planner that cannot be satisfied by ERP or APS. In order to move whole industries further in their planning efforts, the current situation and issues must be understood better next to further developing state of the art planning solutions.

The next section describes three cases that demonstrate the workings of three spreadsheet based planning solutions in three different environments.

4. CASE STUDIES

4.1 Case 1: Scheduling to meet headquarters demand

This first case describes how a Norwegian cheese producer is required to schedule assigned orders to its available production capacity. In a weekly mutual effort between three facilities, ERP production orders are distributed along the facilities. The facilities decide whether they can produce the assigned orders with their available production capacity and transfer orders between them if assigned orders cannot be produced at one facility.

As de Man et al. (2015) demonstrated for this case, the process of scheduling orders on available production capacity could consume up to 2 man days in working hours. The manual scheduling has now been replaced with a new solution, first with a spreadsheet-based tool, later with an APS.

In this case, the Excel tool developed had a benefit: It generated exactly the same results as the planners generated with their original solution. The given solution was therefore accepted and adopted, without any complaints from the planners or management.

The original solution was basic, easy to understand and had a clear visualization. The manual labour required, however, resulted in a 2-day job. This left no time for schedule improvements; the planners where chasing to get a solution ready before the next week, they were not improving a system proposed solution with a given goal.

4.2 Case 2: Managing capacity restrictions

The second case company is a confectionary producer that has a make-to-stock policy (MTS), planning production based on sales forecasts. The second case company both does weekly capacity planning and detailed production scheduling by using custom made Excel solutions.

The weekly capacity planning solution uses the forecasted demand and smooths the demand over the coming five weeks, to achieve an equal workload for each week and avoid that capacity constraints are broken. Spreadsheets are used to visualize the effect of demand smoothing by showing how much labour capacity is required per week. This weekly process requires downloading all future planned orders from the ERP system, changing the starting dates of the planned orders in the spreadsheet tool, and then update the orders with the correct dates in ERP.

After the weekly capacity smoothing, next weeks planned orders need to be downloaded from ERP to create a production schedule, using a visualization that shows what is done each shift on each production line. Production scheduling needs to satisfy several constraints, which is a puzzle that is solved weekly for the different production lines. After creating a production schedule, all planned orders in the ERP system need to be updated to actual production orders with the correct starting date. Changing the planned orders into production orders in the ERP system ensures order release.

The scheduling process needs to be redone during production if production variation results in lower output than expected. This can be due to either equipment breakdowns, personnel problems, unexpected maintenance, or quality issues.

The rough-cut planning, scheduling and re-scheduling takes time of two full-time employees. The planning process generates a weekly plan and daily production schedule, but the time pressure under which scheduling occurs often results in schedules that do not fully reflect all the constraints.

These planning tools came into existence due to three constraints in the ERP system:

- The ERP material requirements planning (MRP) only does backward scheduling without capacity constraints.
- The ERP does not translate the MRP into a detailed production schedule.
- The ERP has limited visualization for both the weekly aggregated needed capacity and the daily production schedules.

While the current planning tools satisfy the need for visualization, they do not show the quality of the solution in another way. As in the first case, the planners chase to achieve one acceptable solution, they do not work on the improvement of a proposed solution. Furthermore, the information transactions between ERP and the spreadsheets, bear risks of data corruption and planning errors that are not detected until a later stage, e.g. when a stock-out occurs.

The main reason for not investing in improvements in the ERP system has been a simple cost benefit equation by management. The rigidity of the ERP makes it hard, and therefore costly, to change the system. While the benefit might be beneficial in the end, changes in production layout or production strategy could result in the need for additional changes in ERP, resulting in a new investment. The case company explicitly expressed the wish not to work with ERP consultants, because both the costs and benefits of their work is often not known beforehand.

4.3 Case 3: Meeting strict delivery precision

The third case describes how a make-to-order (MTO) furniture producer schedules its orders. The premises of the current planning method is simple:

- When an order is received and accepted, it needs to be shipped five weeks later at the latest.
- Orders must be planned for production in the first available week with production capacity.
- Orders must be scheduled for release, i.e. the day the order starts the production process, on one of the working days in the week the order is planned.

The planning in this case company is mainly concerned with the scheduling of order release. Order release is mainly dependent on the use of leather colour of the ordered product. The sequencing of orders with the same leather colour gives an opportunity to better utilise the available cowhides. A reduction of 1% in cowhide waste can save up to €300,000 annually and therefore orders with the same leather colour are clustered on the same production days.

The assignment of orders to a specific production week is done in the first available week with production capacity. The current scheduling process assigns the release of orders to the weekdays of one week that has been specified during order acceptance. During the assignment of orders to weeks, no other constraints then the total available capacity have been considered. This means that the scheduling difficulty is dependent on the resulting order set for that week.

These planning processes result in a full-time job for a planner. There are several issues in the current planning process:

- It only considers cowhide utilization for the available order set, because of freezing the production week for the order.
- Because of the focus on cowhide utilization, the effect of order release on the rest of the production system is unknown.

For the three cases, the spreadsheet solution for this case is the simplest in which the planner assigns all ERP orders to available weekdays based on the colour constraints for the different weekdays. A maximum capacity for order release per day gives the puzzle that the planner needs to solve.

5. TODAY'S STATE OF PLANNING

Why are production facilities still planning with spreadsheets? The developments in computer calculation power, algorithms developed in operations research and availability to off-the-shelf APS should at least incentivize manufacturers to explore the possibilities to extend their ERP systems by building in APS modules.

Spreadsheets, however, still dominate planning as the main tool, and we do not have the end of the spreadsheet phenomenon in sight. The adaptation of APS certainly comes with a set of problems, but that does not mean that they are impossible to overcome. In the cases, however, two lines of reasoning against APS were observed.

The first reason is in the form of not wanting to lose control over the planning process. Self-designed spreadsheets are often well understood by its users. In the first case the developed solution in Excel was better accepted than the later implemented APS, because the planner does not want his planning system to be a black-box.

The second reason is that the benefits of adding extra modules into or next to the ERP system are experienced as risky, while the financial benefit is not clear. In the second case, the manufacturer does not want to involve ERP consultants to build in extra planning functionality. Starting with such a project can lead to high costs, while functionality is not guaranteed in the end.

Spreadsheets, however, lead to today's state of planning for the cases demonstrated in this paper, that come with a set of issues:

- Planning construction and manual labour required

In the first case, the manual labour required to construct schedules has been taken over by two consecutive tools. Before these changes, it took a planner two days to construct a weekly schedule. In the two other cases, planning and scheduling still requires daily manual labour, ranging from hours to several days a week spent.

Programming of planning and scheduling can take over repetitive tasks and with proper programming in spreadsheets, run-time can become acceptable to good, e.g. it took several minutes for the Excel based scheduling tool in the first case to construct a schedule that was accepted by the planners.

- Options for optimization and key performance indicators (KPIs)

Options for optimization were not demonstrated in any of the three cases. All cases demonstrated that the current perceived need for planning was of an administrative kind where orders are assigned to time-buckets and then later to specific resources. While all cases demonstrated different constraints, they did not demonstrate a goal function or a set of KPIs that measure the quality of the resulting planning.

While these cases did not demonstrate such KPIs or goals, it is of course possible to program or structure spreadsheets in such a way that goal functions and KPIs become visible.

- Fool proofing of and errors in planning

The major issue with the use of spreadsheet solutions is that they are never fool proof. Due to the unlimited degree of freedom in spreadsheets, the integrity of data and linkage between data in several sheets can be broken without warning. Errors in the data and use of wrong data for calculations can be part of any spreadsheet without anybody noticing. This means that the use of spreadsheets requires careful handling of input and output data.

For all cases in this paper, it is not clear whether the spreadsheets contain large errors and make use of the right data. Measures can be taken that check for the integrity of the solution, but data integrity cannot be 100% guaranteed.

- The logic behind the spreadsheet solution

In all three cases the goal justifies the means of the spreadsheet solution. Planners undertake repetitive tasks every day, week or month to come to an acceptable solution. For all three cases the logic of the spreadsheet is no longer challenged by the users. The solution is accepted as a means to come to new plans and schedules, not as a customised tool developed to plan or optimize for a predefined goal or set of KPIs.

- Visualization

The visualization of solutions has been called one of the main reasons in case one and two to keep using spreadsheet based solutions. The customization possibilities in spreadsheets can give good insights in planning. Case one demonstrated how different production lines where filled with orders. Case two demonstrates how much expected shifts are needed to produce forecasted demand, and gives insight in how much capacity is used when scheduling. Case three shows both available capacity on weekly as on a daily basis by using graphs.

All case companies said that the degree of visualization in their ERP systems is too limited for the visualizations they want to have in their planning process. This relates back to the fact that planners want to have control over their planning processes and that planning systems should be supportive to that. It must, however, be noted that a visualization cannot overcome or even decay the previous mentioned issues.

- Planning integration and local solutions

For all the cases, planning integration is totally neglected, on both the timing horizon and different PPC functions. All solutions consider their input information as given and give little to no reflections on the consequences of their output. All cases solve capacity problems, and do not consider material requirements. This leads to a local solution that only uses ERP information that is relevant for the task at hand, without any feedback loops between different planning levels and different company functions.

The effectiveness of spreadsheet planning tools can be questioned. While the tools fulfil all the requirements and support that are requested in practice, there are several limitations and issues that make spreadsheet solutions ineffective. What the cases have learnt us is that spreadsheet solutions are evolutionary products coming forward from interrelated developments, not in the least the choice of ERP system that lacks needed functionality. It has also been shown that spreadsheets are the low-cost solution for each problem. The quality of each solution is, however, dependent on all the factors mentioned in this section.

6. CONCLUSION AND DISCUSSION

In this paper we demonstrated that the use of spreadsheets in planning is still dominating over the use of ERP and APS for planning purposes, helping planners in making planning decisions on a daily basis. ERP often only offers MRP, which is insufficient for planning and scheduling. At the same time APS solutions are still not common practice in industry, because manufacturers are either avoiding the investment risks, or do not want to lose the control over their planning process to an algorithm.

Practitioners still struggle on a daily basis with the planning, scheduling and dispatching tasks they perform in spreadsheets, but their managers are at the same time very hesitant in adapting new software for planning. While the case data that is used in this paper is from 2015 to 2017, this paper could have been written 10 or 20 years ago, finding similar problems with MRP, ERP and APS that results in practitioners using their spreadsheets to save the day. These insights are therefore crucial in further PPC research, especially for firms in practice that are still dependent on legacy systems and spreadsheets.

This leads to an interesting discussion in which we see a big development in computing power and algorithm development on the one hand, and production planning and scheduling not showing significant improvements in practice over the last twenty years on the other.

So how to move forward the research field? We should keep moving forward our research field in studying and developing state-of-the-art planning, but we must not forget that all around the world there is tens of thousands of cases in which planning processes take place in spreadsheets, both in basic and advanced forms.

This leaves room for discussion on the future of spreadsheets in PPC. The use of spreadsheets in itself is not wrong, it can even lead to good results if designed and programmed in a proper way. Although we think that spreadsheets will remain part of PPC in next years, we see a growing research focus on concepts such as digitalization and Industry 4.0. These concepts focus heavily on automation of decision-making by using big-data and advanced algorithms, and are therefore not aligned with how spreadsheets are currently applied in PPC. Spreadsheets are currently applied to gain better control, or at least a better sense of control. The discussion, however, on the role of spreadsheets is very limited in current and future PPC. Therefore, we must not forget that spreadsheet applications still dominates over ERP and APS as the main support for planners in their daily work.

The next question then is on how to move research on the use of spreadsheets forward. First, descriptive case studies on modern day use of spreadsheets could give a better understanding of why spreadsheets still play such a large role in planning. Second, guidelines and cases on how spreadsheet application can be improved and should interface with ERP and APS can be beneficial as long as planners keep using spreadsheets for many planning decisions. And lastly, research needs to remain focused on how companies can make the transition from spreadsheets to planning systems that are fully supported by ERP, APS and future systems, especially in the digitalization and Industry 4.0 age.

The limitation of this study is that the observations have not been compared with a case study in which no spreadsheets are longer used in PPC. This must be addressed in further studies, to further test and compare the issues found with spreadsheet planning.

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