ERP-Planning Garbage: Realizing and Preventing

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Abstract MRP II is still the planning core of most ERP-software systems and practically usage with well known but often ignored weaknesses. These weaknesses and their reasons are described in detail. Most APS are concentrated only on partial planning aspects with insufficient results. Until now all well known OR methods prove as unsuitable to solve the high complex planning ERP tasks for practical use. Rolling Detail Planning (RDP) is an approach, which changes fundamentally ERP-MRP II philosophy. TPS is an innovative alternative software system based on simulation techniques and fuzzy logic by realizing RDP. It claims to avoid the faults of MRP II based software systems and to get over the weaknesses in calculation, concepts, transparency, and cost of OR based APS.

1 MRP II is Still the ERP Planning Core

In ancient times the powerful King Agram reigned a large empire. His people were living in peace, freedom and wealth. One day Agram fell off his horse and broke both of his legs. The doctors were unable to heal his legs so that he could not walk again without crutches. He lost his will to live and neglected his royal duties. An assembly of the elders therefore decided to force all the people also to walk on crutches as a sign of solidarity. With time walking with crutches became normal and identified the people. Only a few could image life without crutches. These few began to realize that only those can be happy who throw away their crutches and walk on two legs [1].

For over than 40 years Manufacturing Resource Planning (MRP II) has been the planning core of the most of Enterprise Resource Planning Systems (ERP) with

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all its well known but often also hidden and forgotten weaknesses. Nevertheless most ERP users are well satisfied with their ERP software, as is shown by the 9th worldwide satisfaction study (Zufriedenheitsstudie) in 2012, containing 1923 companies in 17 countries. But only 69 % of them still define functionality as the primary software selection criteria. Focus is shifting to internationalizing, adaptability, and ergonomics of the systems [2]. In addition to the development of many specialized ERP software solutions countless so called advanced planning systems (APS) appeared and much of them also disappeared again during the last 30 years. That's the fate of weak systems, that they are depending on "the basic law of systems: poor systems breed more systems" [3]. For many software companies' life is not too bad by only partly curing ERP weaknesses (they are recycling the planning garbage by serving golden crutches) and most users and many of their employees are well accustomed to live with those weaknesses and all their lovely crutches they have. Often they are defending violently those crutches, fearing changes or fearing to lose their job when the crutches are taken away from them.

Most ERP-solutions and other IT-applications in usage today are based on MRP II. Precursors are the Bill of Material Processor (BOMB), early in the 1960 pleaded by Josef Orlicky, and Material Requirement Planning (MRP) already early in 1972 pleaded by Oliver Wright [4]. The impetuous IT-development made it possible to expand MRP by including capacity planning, shop floor control, and purchasing at least theoretically to "Closed Loop MRP", and by including the important financial functions to Manufacturing Resource Planning (MRP II) [5]. Oliver Wright stated in 1981 that MRP II "is not a new 'theory' on industrial behaviour, it is all fact. MRP II is what's happening today in a number of companies" [6] and he mentioned Black & Decker, Cameron Iron Works, Corning Glass, Hewlett Packard, Steelcase, Tennant, Xerox [6]. The extension of MRP II to ERP (Enterprise Resource Planning) includes all pre- and post-manufacturing activities from order acquisition up to the after sales services. This also will include SCM and CRM, whereas MRP II still remains as operating planning core. In effect, ERP could be thought of as a customer-to-customer cycle [7].

Figure 1 shows Wight's MRP II Standard Diagram. At a first glance it appears relatively simple. But also it is very comprehensive. It could include the total planning system of every manufacturing company. All steps also include financial activities and constraints and scheduling. It is applicable to all production systems—discrete, process, line—, and to all marketing strategies—make to stock (MTS), assemble to order (ATO), make to order (MTO), and engineering to order (ETO). In 1980 increased computer capacity already made it possible, to break down the time phase of ordering into monthly and weekly time periods [8]. But the main attention has to be directed to the closed loop idea and its requirements. The numerous arrows within the diagram should clarify this. Rescheduling on all levels has to ensure, that all production, procurements, financial activities, policies, and regulations are to be synchronized within the total company.

Already in 1980 Wight emphasized, that modern computers and the knowledge that had been developed in the application of this knowhow over the last 30 years, made it possible, to provide the techniques for the company game plan. "How

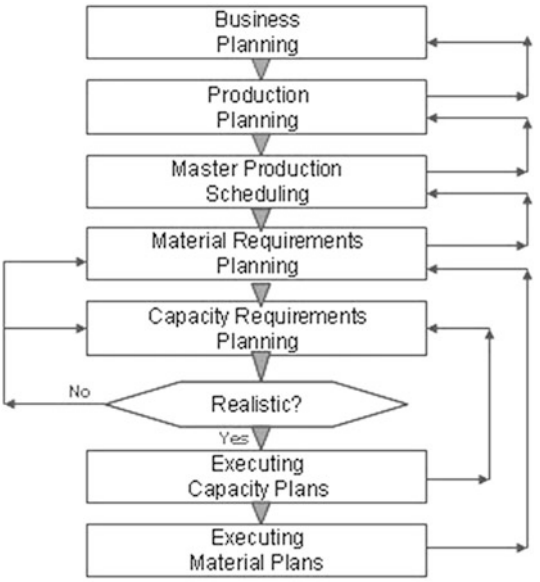

Fig. 1 MRP II standard diagram

effectively these techniques are put to work is up to the people who run a manufacturing business" [9]. However the question at present is how IT-companies 30 years later have carried out this origin MRPII vision by developing adequate software solutions as well as how the users are handling the planning of their manufacturing business.

2 ERP Planning Software Weaknesses

In order to be correct, the original MRP II vision of Oliver Wight, as shown in Fig. 1 contains no statement about any planning method. The idea is just a sequential planning in several steps, with an overall synchronisation of all activities in order to fulfill customers' requirements by means of companies' production. ERP Planning weaknesses therefore are weaknesses of software systems and its usage.

2.1 Demarcation of ERP Software Planning Solutions

Over the last 30 years ERP software solutions have developed dramatically in functionality, but today still don't include the first two stages of business planning

and production planning. Both are planning activities with a strategic dimension. They not are involved with operational activities. Fact is that in reality business and production planning are still and often pretty miserable. The business plan should deal with policies that among others aim at market position and manufacturing shape. The production plan contains in more detail organisational strategies and development of marketing strategies as well as production systems. So far ERP software solutions mostly deal exclusively with operational planning carrying out manufacturing to fulfill the market demand. In the 80s those systems were called Production Planning Systems (PPS). In 2011 the ERP-systems of some well known IT-vendors (APplus; Canias ERP; EPICOR 9; M3; Microsoft Dynamics; SAP ERP; Semiramis/Comarch ERP) where tested by GPSmbH and all were awarded with "ERP Excellence". All had to undergo eight different test scenarios, but again typically no test referred to planning or planning methodologies [10, 11]. For many years this has actually been no subject of a discussion. Only partial planning and its methodologies are mentioned in context with manufacturing execution systems (MES) and APS.

Most of ERP-vendors nowadays are not only selling solutions imbedded with simple MRP II functionality. All above mentioned ERP-solutions provide an Advanced Planning System (APS), but without describing the planning methodologies that are applied and the interface to the planning functionality of the main MRP II system. Nevertheless it seems convenient at first to explain the weaknesses of ERP-systems without APS. This also makes sense because many users still are using older ERP or PPS systems without APS. As a typical application of a MRP II based ERP software solution the well known SAP R/3 will be used as an example. In addition and on the contrary to other ERP-vendors' systems a huge series of publications are describing SAP R/3, SAP ERP, SAP SCM inclusive enhanced Advanced Planner & Optimizer (APO), and many additional ERP modules; for details see:[12]. Gronau reports, that in 1998 SAP had installed about 20.000 R/3 systems [13] and 14 years later, in 2012, SAP informs having about 183.000 costumers [14].

2.2 ERP-MRP II Weaknesses

Weaknesses of a manufacturing scheduling system have to been judged by their ability to calculate and maintain valid due dates of requirements and availability of resources. Those dates are start- and end dates of any manufacturing activities, of any type of orders, of resource availability, promising, delivering, and ordering. Wrong, rough-cut, or inaccurate dates will cause delays, bottlenecks, inadequate availability of resources, additional costs, and simply many not assessable problems. Inadequate time periods such as weeks, months, or determined by dates, also have a big influence on the calculated quantities of all sorts of inventories and backlogs. This will influence availability of resources and of course the cost of manufacturing.

Without a doubt, weaknesses of an ERP-IT-Solution are causing errors in the manufacturing process which results in financial losses. Consequently the manufacturing activities meet the company's' customer requirements insufficiently. Dealing with those problems, we have to distinguish software construction faults, inadequate handling by users, and inflexibility of both to cope with the continuous environmental changes in the market requirements, technique and business.

Another point of view is the tremendous interdependence of a fault or defect caused by a weakness e.g. customer order backward scheduling of a deeply structured product without attention to constraint capacities; look at Fig. 4. This causes a long chain reaction:—false purchase and manufacturing start dates—insufficient inventory of parts—higher costs—waiting periods in the shop floor—higher work in process and higher costs—additional production bottlenecks—longer lead times—delays of delivery—annoyed customers—and so forth, and so on. Such a functional system weakness is causing every day with each customer order results in hundreds and more mistakes and defects. Perhaps some of them will neutralize one another on another level within planning or production. More of such weak planning points, caused by software functions are multiplying defects in the manufacturing process. All three MRP II operating stages show together some quite serious and coherent weaknesses. The most important are false start- and end dates of orders and of most manufacturing processes, caused by scheduling ignoring limited capacities, backward scheduling, and rough cut planning [15]. The following numerical and graphical examples should clarify these statements and support the understanding of the serious reproachful claims regarding the present ERP planning solutions.

Table 1 Comparison scheduling with unlimited and limited capacity

Orders	Requirements			Income day	Unlimited start day	Capacity end day	Limited start day	Capacity end day
	1	2	3					
Order 1	1500	1000	1500	1	1	3	1	5
Order 2	1300	400	500	1	1	3	2	5
Order 3	1500	600	2000	2	2	4	3	7
Order 4	2000	1500	1000	3	3	5	4	9
Order 5	2500	1200	2000	4	4	6	6	11
Order 6	2000	300	1750	5	5	7	8	12
Total	10500	5000	8750					
Max.capacity per day/shift	1200	1000	1500					
Assumptions								
3 capacity units Wanted delivery day = 8 handling over next day				1 shift per day Leadtime = 3 days + 1 day savety handling over time : 4 h (quality control,transport)				

2.3 Scheduling Examples

Table 1 shows a simple scheduling example with 6 orders to produce on 3 different working places (e.g. machines) with different time requirements.

Further assumptions are: one shift per day with different time capacities per manufacturing unit, order income from day 1 to day 5, due date for all 6 orders is day 8; handing over from one machine to the following one needs 4 h (e.g. quality control, transport, set up); planning rule unlimited is handing over next day; calculated lead time therefore is 3 days plus one safety day.

Table 1 shows the different start and end dates between scheduling with unlimited capacities and limited capacities. In case unlimited all is o.k., in case limited only the first 3 orders can be delivered in time. Figure 2 and 3 clarify the problem in detail.

The ignorance of capacity constraints in Fig. 2 leads to quite false results, no start and end date reflects the real possibilities. Figure 3 shows workplace 1 obviously as a bottleneck unit with the consequence of underemployment of the two following workstations. Both units show typical gaps, which normally occur in scheduling process. Most ERP-vendors and numerous IT- and OR specialists often futile try to stop or to avoid these gaps in a convenient way. Looking at six orders one can recognize the gaps, its causes and development. But on scheduling some hundreds of orders already in a midrange manufacturing company gaps are often covert by evasive orders or jobs. Fact is that early recognition and avoidance of bottlenecks and gaps in manufacturing processes need a scheduling in view of restraints of all necessary recourses.

In this context backward scheduling with unlimited capacities as shown in Fig. 4 appear as an absolutely incomprehensible and really ridiculous planning method.

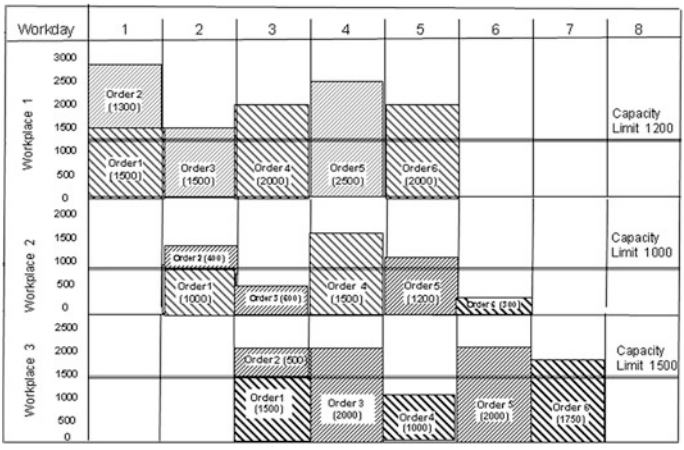

Fig. 2 Forward scheduling with unlimited capacity (1 shift per day, handling over next day)

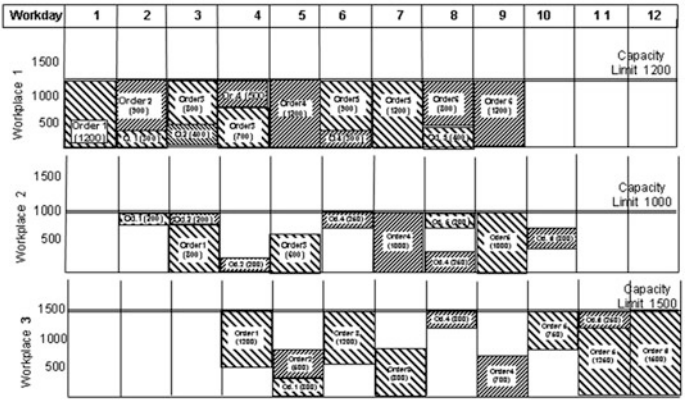

Fig. 3 Forward scheduling with limited capacity (1 shift per day, handling over next day)

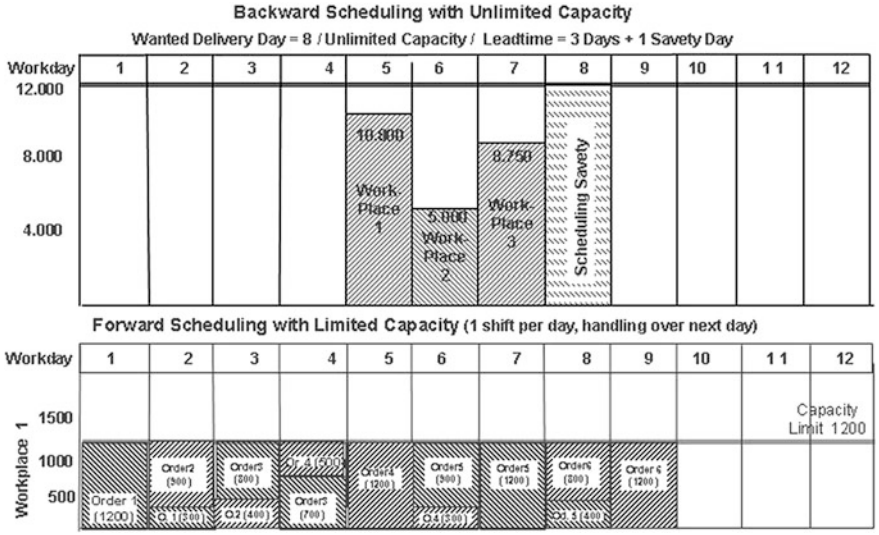

Fig. 4 Comparision unlimited backward schedudling with real forward scheduling

In Fig. 4 using backward scheduling the start date of all 6 jobs for workplace 1 are concentrated upon the 5th day with 10.800 time units and an available capacity of 1.200 units per day. We know that already starting at the 1st day is necessary to deliver at least the half of orders in time on day 8. Also as far as unlimited backward scheduling it used only as rough cut planning the date for provision of all sort of recourses always is false with all negative consequences.

And in general backward scheduling without or with limited capacities is a futile attempt also some ERP vendors are advertising with these method. Often

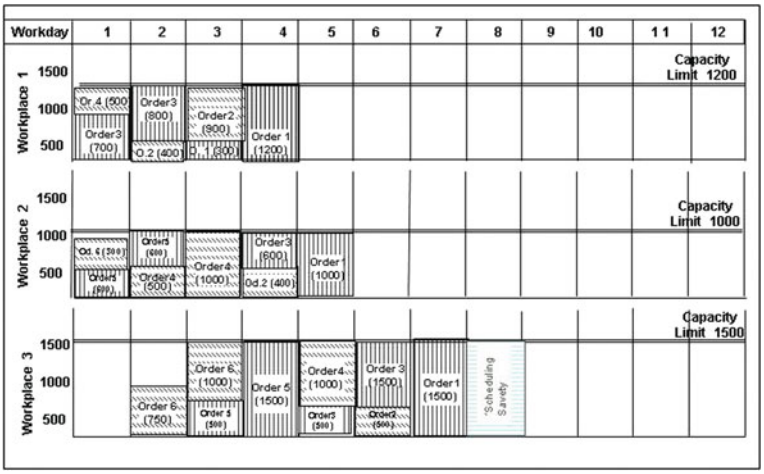

Fig. 5 Futile attemept at backward scheduling with limited capacity

backward scheduling is ending in the past as shown in Fig. 5. Only three orders can be produced, obviously starting with order 4 instead of order 1. That's why a start at actual date with all orders forward scheduling is to be done. An other crucial point is the question in what sequence or with what priorities backward scheduling has to start. Starting with the highest priority results, that orders with lower priorities are earlier finished. Starting with the lowest normally ends in the past.

We can conclude that scheduling without regard to limited recourses results in false start and end dates and that backward scheduling in this context is an inappropriate planning method.

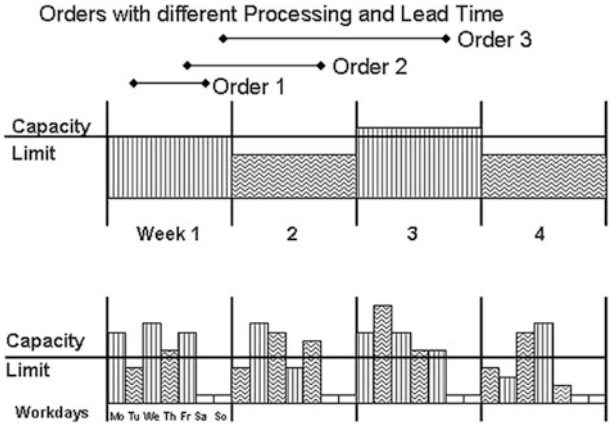

Fig. 6 Rough cut planning versus detailed planning

Figure 6 shows the problems of rough cut planning versus detailed operating planning. Planning with time buckets (weeks or months) with available due dates within the buckets make plans as basis for decisions unnecessary misty and spongy. Limited IT capacity and missing planning know how only could be an argument 30 years ago.

Rough cut planning make day precise Available to Promise impossible, discernible bottlenecks unknown and countermeasures in time impossible. Always rescheduling and troubleshooting within actual time buckets is necessary. Orders with lead time longer than a time bucket (see Fig 6, order 2 and 3) or across time buckets are causing daily many manufacturing challenges or troubles. To provide material and capacities in time needs detailed scheduling for the total operating planning period.

Details and explanations of these serious reproachful claims will be treated with regard to the three MRP II stages that ERP-software solutions normally contain.

2.4 Master Production Scheduling (Master Plan)

Figure 7 shows the rendering of the MRP II idea to the software system SAP R/3. It contains the operational part of MRP II with master production scheduling,

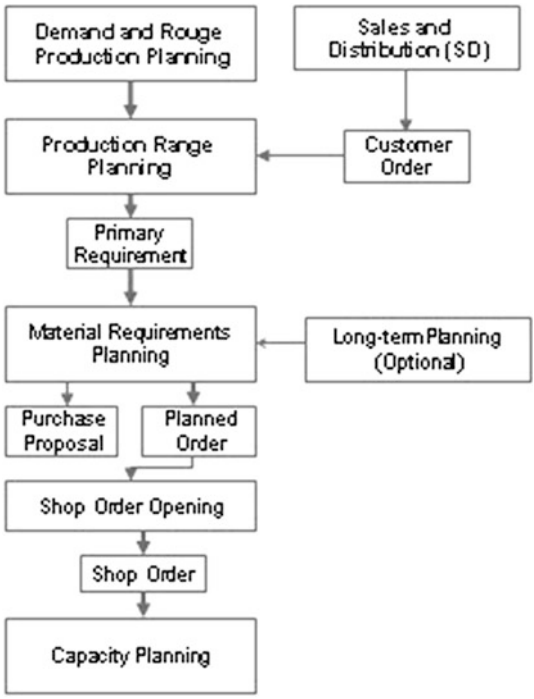

Fig. 7 SAP R/3 production planning (PP)

material requirements planning, and capacity requirements scheduling. In contrary to the MRPII standard diagram (Fig. 1) Fig. 7 contains no recurring arrows. This means, the software itself is running without the necessary closed loops. Regarding this planning approach, it's a poor hierarchal sequential system and an insufficient reflection of MRP II regarding the planning part; details refer to publications [12].

Demand and Rough-Cut Production Planning and Production Range Planning correspond to MRP II Master Production Scheduling. It has two functions: demand or sales planning (sales plan and forecast) and production planning. The sales planning horizon is usually 1 year divided into 12 months and should be organized with monthly reviews rolling 1 month forward. In real life many small and mid-range companies are not planning monthly sales in product units, but if they are, than only as monetary amounts of sales income. In this case the total manufacturing planning depends on sales order backlog and new incoming orders. Occasionally the material management indirectly assumes the necessary forecasts by anticipated purchasing. This situation could be adequate in some business environments (e.g. long range projects, machinery). But otherwise it represents a severe management inability which is causing many uncertainties and fluctuations in all the following planning and operating processes.

In order to reduce calculation time demand planning and forecasting is done in product groups or only for the critical units (lead units—Leitteile), in cases were a company has very many items [16]. Production planning is a rough-cut capacity planning. Also resources (e.g. workplaces) are aggregated to capacity production groups. Comparison between demand and relevant capacity within the different planning time periods—normally month or weeks—shows capacity overloads. These overloads have to be balanced interactively, that means manually to the rough-cut production plan. In the next module, production range planning, the output of the rough-cut production plan is matched with the backlog of customer orders. Monthly output of the production plan has to be distributed to the days of the period, while the integrated customer orders from the beginning are scheduled for the delivery days. All delivery dates are assumed to be requirements which could be fulfilled without checking resource availability. The output is a plan containing sales, production, and inventories of planned products distributed within the time periods of the planning horizon.

This output of the master plan contains a series of weaknesses regarding the further planning process. Planning with product groups and only critical parts as requirements against group resources using big time buckets is absolutely not satisfactory to ensure the proper identification of temporary overloads on production resources. Planned delivery dates don't correspond with the required start date and work period of required resources. Further on the daily required availability of a single resource within a single time period is very uncertain. Bottlenecks within and during the planed time periods can not be discovered. As a result dates and quantities of the primary requirements submitted to material requirements planning are not only uncertain but show inaccurate and therefore incorrect dates, due to the rough cut master planning. But master schedules are the basis for

scheduling material requirements and accepting new incoming demands by the process called available to promise (ATP).

2.5 Material Requirements Planning

MRP corresponds to SAP module MM. In general it comprises the coordination of customer demand and requirements of material within the limits of an unsatisfactory master plans' output. This involves promising customer demands (ATP Available to Promise), managing all material inventories, planning purchase and production of material, and releasing shop floor orders.

A planning run of MPS (Material Planning Schedule) starts by comparison and reservation of the primary requirements,—these are customer and plan orders—, with available stocks of products to be sold. If not available the products and it parts have to be purchased and/or produced. The remaining orders have to be exploded down through their product structures. Start- and end dates are calculated for every part of the product in view of its individual lead time. In SAP R/3 and most other ERP systems order scheduling is done backwards from demanded delivery date as due date. The start date is calculated by subtracting the lead time from due date, whereas lead time often is increased by the planner for safety reasons. Only if the start date lies in past, forward scheduling is executed. First output is the required quantity of the different parts, with individual start- and end dates, called gross requirements. Debiting the available stocks, actual purchase orders and actual shop orders, the net requirements remain. Every part of the net requirements has quantities and an individual start and an end date. Wrong dates are normally already applied by using an incorrect lead time and additional safety time on top. The total calculation, however, is not taking the required capacity constraints into consideration. As a result often start- and/or end dates of many orders and their parts of ordered products are assigned to the same planned manufacturing time period without sufficient production capacity. Another crucial point is represented by the sequence of the orders to be processed. Most ERP solutions have no functionality to handle customer and shop floor order priorities in the required or in a satisfying way.

Net change methodologies are used for new incoming customer orders, in order to avoid a time consuming new planning run. This software module is generally called Available to Promise (ATP). It works after a MRS run is already completed only for a single order, but only the uncommitted amount of the inventory and of planned purchase- and shop orders within the MM module (Material Requirement Planning) will be applied as available. Wrong times are like the MPS faults, but orders with a later delivery date, scheduled earlier or in last MPS run, often are blocking later urgently required material. Those blocked new orders either imminently "get lost" because of promising insufficient delivery dates or become urgent orders with all consequences of trouble shooting within the manufacturing process.

A great deal of other planning weaknesses originates from inaccurate inventory, purchase management and lot sizing. One main issue is planning with high safety stock. At the end inappropriate stocks are caused by false or missing due dates as a result of the inaccurate scheduling and often missing customer order planning. The result is unforeseeable high deviation between planned and actual requirements. Often some material is required earlier and other material later. Stock replenishment therefore is often uncoupled from MPS (Master Plan Scheduling) through stochastic inventory planning by the material management. For this R/3 delivers more than 30 different methodologies in the system. Another source of weaknesses is lot sizing. No order determined inventory planning and the pooling of common components necessary for different customer orders uncouple purchasing and manufacturing from the customer orders. Lot sizes in purchase and manufacturing often are higher as really required in respect to cost savings. This will increase inventories, block production capacities and extend lead times.

SAP R/3 offers optionally the module Long-term Planning. This is a tool to simulate alternative demand forecasts. Scheduling works like material requirement planning. Therefore it is not really able to measurably reduce or change the above mentioned weaknesses.

The results of Material requirements planning are purchase proposals and so called planned orders for parts to be manufactured. The material availability for these orders is monitored in module Shop Order Opening. Those orders with start dates within the next time bucket, mostly a week, are released into shop floor to be executed and controlled either automatically but more often interactively by the workforce.

2.6 Capacity Requirements Planning

Capacity planning of most ERP-software is defined as detailed short-term execution and control module of the shop floor orders. The shop floor is the last link of the continuous requirements planning chain. Looking at the shop floor input one can see best the consequences of the on-going planning weaknesses. Short-term time periods normally are days. Machine capacity is planned in detail for work days or shifts taking into consideration the planned availability of manpower and partially the availability of required tools in the production process. This is absolutely insufficient for execution and control for the production on the shop floor. During a shift every workplace needs a detailed schedule normally based on minutes and the information of the sequence in which to manufacture the job orders. In addition the dates of released job orders are results of predetermined rough lead times which inherently are inaccurate. Scheduling of orders and the corresponding jobs on different production capacities again is usually done by scheduling backwards. By scheduling backward as well as by scheduling forward unavoidable there will occur time leaks of available capacities and job orders with too long processing times to fit into these leaks. Normally one tries to solve these

planning problems interactively e.g. manually. Outstanding tools therefore are 'electronic control stations (Leitstände)' with user-friendly graphical displays based upon the classic Gantt chart format.

Altogether planning data input on shop floor result in "planned garbage", which has to be recycled in order to be at least able to reach a sufficiently accurate planning result. A detailed fine tuning is necessary which aligns all the requirements within the boundaries of the finite capacity that is available.

The weaknesses of applying the origin MRP II goals into sufficiently effective software systems is demonstrated by the ever increasing development of external Manufacturing Execution Systems (MES) [17–19] and countless Advanced Planning and Scheduling (APS) systems. MES solutions have multiple functions relating to the control the production process in very different environments. But in respect to planning they are recycling planning garbage of the previously executed master planning and material resource planning. This can cure only a partial portion of the total weaknesses thus causing financial losses and insufficient achievement of the other goals of the company.

2.7 APS Contraints

One major ERP planning weakness generally was accepted by IT- and OR scientists, as well and imperatively by IT companies: scheduling against infinite resources has to be changed by finite or constraint planning. This is the main source and objective of the development of most Advanced Planning Systems. The term Advanced Planning System (APS) might seem to imply that such a system is beyond and better than a system based on MRP II. But some doubt is required because of two reasons. First a system containing the entire production functionality as described in Fig. 2 will fail because of its complexity and the restrictions of applied OR methods like Linear Programming (LP); Mixed Integer Programming (MIP) [20], Genetic Algorithms (AG) [21], and Constraint Programming (CP) [22]. Secondly for this reason most APS deal only with one MRP II module or with a hierarchy of modules corresponding to MRP II structure [23]. And obviously the same planning approaches as in MRP II are used, with rough cut planning in Master Plan, with backward scheduling in Material Requirement Planning [24]. One has to assume, that the same weaknesses and faults are arising, which are existing in ERP-MRP II solutions.

The SAP APO system corresponds far, with the R/3 solutions [25]. In this regard one can assume that at least similar faults will occur as described in MRP II. Apparently again generally a multi level approach, at least a two level approach is implemented and obviously necessary. The first level (APO-SNP), optional to use, works as a rough cut scheduling system. The restricted usefulness of such an output was described above. The second level "Production Planning/Detailed Scheduling (APO-PP/DS)" again has two levels: Material Requirements Planning and Capacity Planning, the latter with detailed scheduling based on minutes or

even seconds. But scheduling works only within a time period of 1 day to 1 week. As an alternative the planning input for detailed scheduling can be taken from ERP base system. Many functions have to work interactively, that means by many different planning specialists at the same time. The applied mathematic methods and the calculation steps are unknown to the user. The system is like a black box. Although the APO DS delivers many interesting features, especially with regards to Online Transaction Processing (OLTP) it appears that it gets planning garbage again as data input. With very great efforts regarding constructing models, using highly sophisticated LP software, huge input of manpower, of computer capacity, and of capital, the output appears to be only recycled planning garbage in regard to an effective smart operational production planning system. Generally one can agree to the opinion of Hartmut Stadtler and Christoph Kilger, that it will be a long way until we will reach satisfying and efficient APS [26].

2.8 Conclusion

On every of the three operating production planning stages ERP solutions show a multitude of planning weaknesses. The most important are:

- no clear priorities of customer and shop floor orders;
- only rough-cut planning in master production scheduling
- insufficient consideration of capacity constraints;
- often loss of contact between the customer order and shop floor order and relevant priorities.

Crucial results are false start- and end dates of orders and of most manufacturing processes. This causes many unforeseeable and often incomprehensible faults and leaks on every planning stage. Many of this must and will be cured by interactions between software system and the manual work of many different planning specialists. Others insufficiencies are handled from case to case or will be simply ignored. On this track MRP II, from Oliver W. Wight described as a formal, optimizing system, is shifting to a fragile informal system. Or, the system was all the time a weak, delicate, informal system, and software vendors are arguing, that any faults using their systems always are depending on inadequate or incomplete usage by the end users.

Mostly companies and their employees have gotten used to those defective planning-, information-, and manufacturing- processes and activities. Results are: they have forgotten about the potentials of a smart, cost saving, formal total manufacturing solution and also to think about and claim a lean, simple and cheap solution. Every day the upcoming mistakes and defects have to be cured by additional manual work, by experts, conferences, troubleshooting teams, “date chasers”. The companies and their employees are using crutches like king Agrams’ people.

3 Rolling Detail Planning the Planning Paradigm Change

Paradigm change in connection to ERP means a fundamental alternation of the total operating planning process, its objectives, methods, and applied information techniques. Instead of separating into long range and short range planning only detailed short range planning on minute- or second base is used for the entire operating planning period. No backward only foreword scheduling is done, all in consideration to finite capacities. Because principally most work on orders can only be done sequentially, prime attention has to be directed towards the sequence of processing customer orders, in order to fulfil customer demand in time. Therefore order priorities are essential elements of the total planning process. Its data volume is too huge and process structures are too complex in order to solve the whole detailed finite scheduling with mathematical method as LP, MIP, or CP. By applying heuristic simulation combined with fuzzy logic the exercise can be settled relatively easily and that with low computing capacity. In contrast Bella and Layer are mentioning that LiveCaches of SAP APO not seldom have a dimension of some dozens of gigabytes [27]. Breakthrough to avoid most weaknesses and faults caused by MRP II based software is realised by changing and simplifying planning process and planning method.

Rolling planning means that daily planning or planning in shorter time periods is necessary for the execution of a total planning cycle, taking in consideration all countless changes from order receipt up to recent events on the shop floor. Results are up to date and flexibly respond to every day's changes.

RDP uses all available planning information (facts and plans) of the basic ERP system, and executes an overall capacity plan on a minute base. This will guarantee precise start- and end dates on every planning stage.

In order to support and improve forecasts RDP works with flexible planning horizons for every product. Horizons are determined by lead time of purchase and production. Using rolling planning it is not necessary to work with longer planning periods and more planned orders than required.

Although RDP is a sequential planning system it includes in every planning run all relevant functions with all data relevant to the planning process, thus integrating sales, material, and capacity simultaneously. RDP works with clear priorities, some simple rules, and some optimization criteria. It minimizes the requirement for interactions by presenting reliable planning information. RDP looks at company and it operation planning as an open and learning cybernetics system. It supplies through daily total planning runs all necessary plan corrections and further adjustments as well as all information to control order promising, purchasing, inventories and manufacturing.

4 TPS: Planning and Simulation with Fuzzy Logic

Total Planning System (TPS) is the ERP-APS, which completely incorporates objectives and methods as used by RDP. Figure 8 shows the planning structure of TPS. The first stages of Fig. 8 contain the demand planning, which has to be done by the basic ERP system. It starts with the long range sales plan, the demand output of the strategic planning and framework for the midrange operating plan. The operating plan normally has a planning horizon of 1 year and should be reviewed and performed monthly. The planning horizon also can be shorter as 1 year with regard to shorter lead time of material and production. Only with regard to the potential availability of a product it is necessary to predict a possible order receipt. Normally, the shorter the period, the better could be the forecast. In addition, the planning horizon can be different for the different products. Demand requirements in a shorter planning horizon cause no difficulties. The planning horizon of TPS reaches automatically to the latest order delivery date. Output of

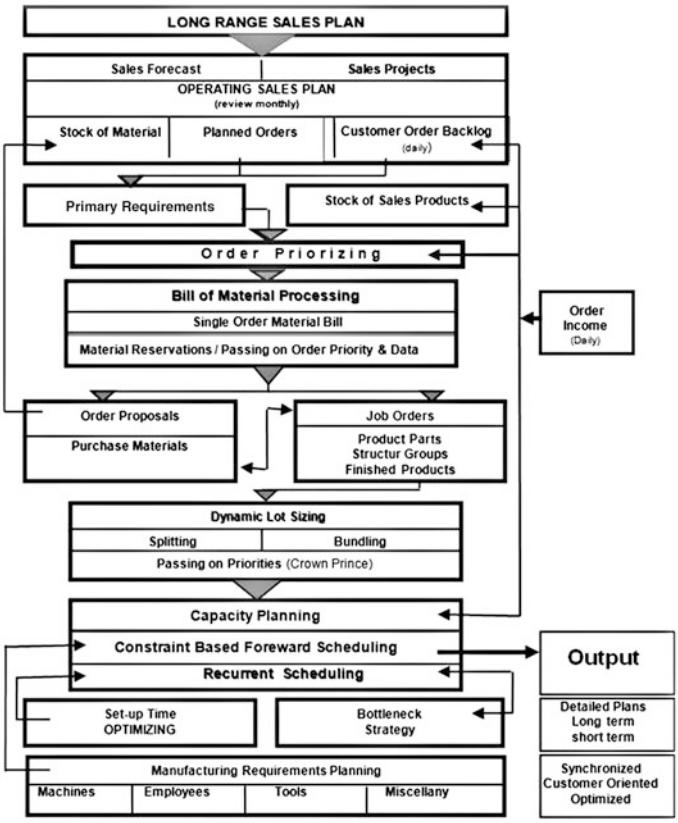

Fig. 8 TPS planning structure

the operating sales plan is the primary requirements. It consists of planned orders, customer orders in backlog, and daily order receipt. Planned orders are the sum of sales forecast and sales projects output, not grouped in any way but for every single sales product. Due dates have to be fixed to a day within the different time periods, normally towards the middle. The customer order backlog contains all actual orders, also those already in work in process, those with overdue delivery date or dates in the past, others beyond the planning horizon, and others with a fixed and promised delivery date. The status of an order is important for organizing further planning and manufacturing, and thus to prioritizing. Daily order receipt changes the stock of primary requirements every day. It contains all different sorts of delivery request, also very urgent ones. All the new orders coming in will be promised first after a completed TPS run. Thus all urgent orders are integrated in the sequence of manufacturing in consideration of availability and urgency. Set off of new customer orders against planned orders can be worked on before prioritization or within bill of material processing in an automatically or interactive mode.

The real TPS run starts with the time dynamically prioritizing of all orders contained in the actual stock of primary requirements. Priorities are calculated by the user's individual criteria. This can be different kinds of promising (fixed, precisely, within a period, and so on), actual dates or planned overdue dates, and orders for special customers, for stock of sales products, for plan orders. In practice the desired delivery date often plays a dominating role. Time dynamic prioritization means, that a promised delivery date gets more urgent every day and will get a higher priority. The priorities are newly calculated with every TPS-run regarding the actual status and are passed through to material resource planning, lot sizing, shop floor orders on all manufacturing levels as the main key to controlling work order sequence, resources availability and fulfilment of promises to customers.

In next step, bill of material processing, demand and customer orders are exactly processed successive to the calculated order priorities. All material reservations will be released, in order to save new reservations again and only for one day for the new calculated urgency of orders. The orders will be debited from available stock, regular purchase and job orders, and reserved orders until the next TPS run. The part structures of products consisting of several or many parts will be exploded down to the lowest level. All parts will be assigned correspondingly with the priorities of the planned- and customer orders. In case of unavailable purchase materials, the proposed material availability is calculated under consideration of individual purchase lead times. Output is proposals of purchase orders and all work orders, which differ between planned orders and customer orders. Decisive for a cost saving inventory policy and recommendation for the usage of TPS is, that all material requirements planning should be bases on this planning process, minimizing all other stochastic planning.

In order to retain work orders, which are meant for use on the shop floor, TPS contains a module for a dynamic lot sizing optimization. For all material to be produced minimal and maximal lot sizes and available ranges are calculated using fuzzy logic. The available ranges determine a number of planning time periods,

which can be different for every part. The job orders are sorted into the planed different time periods in accordance with their delivery date. Smaller orders are bundled to manufacturing orders and large ones are split by requirement and spread to the next planning time period. Bundling means, that different orders with different priorities are combined together. In this case the bundled factory order gets the priority of the order with the highest priority. This is called crown prince principal and will cause, that parts, designed for other customer orders are earlier produced as needed in regard to a cost saving lot size. Parts for one customer order can be spread over manufacturing orders with different time periods. But capacity planning in sequence to priorities fits the right manufacturing sequence. The total lot sizing program will change every day because of new customer orders, new priorities, and events on the shop floor. What counts is the work to be done today or during the actual shift. Tomorrow the sun rises with a new actual plan to be executed.

Capacity planning is done sequential accordingly to the order priorities for every single customer order, mostly with its parts spread over different manufacturing orders. Scheduling is executed straight forward and straight against constraint capacities, bases on 1,440 min a day. Scheduling starts with the part of the lowest level, which passes on its end date plus transportation lead time as possible start date to the orders with parts in the following level. Thus product orders with multi levelled structure are correctly scheduled. In scheduling inevitably leaks of available capacity will occur and in addition orders with too long processing time for currently available resources. For these cases TPS has a comfortable tricky solution based on fuzzy logic. The planning of available manufacturing capacity has to take in account the availability of combined resources as machines, employees, tools, and miscellaneous other resources. These different availabilities are also planned and optimized by TPS. A special aspect and solution refers to set-up optimization. The described scheduling method shows every bottleneck at each capacity unit for every day and for every minute during the entire operating period. These are the waiting queues of orders in front of capacity units to be calculated, analysed, and visualized at every minute of the total planning period. TPS serves in time the necessary transparency to avoid bottlenecks, which have to be handled interactively by TPS simulations. In addition TPS contains a series of program modules to solve special requirements for instance:

- Alternative working sequences on various capacity units with scheduling and optimization;
- overlapped production with constraint based scheduling and time optimization;
- tool scheduling under consideration of combined multi tools;
- usage of flexible production lines;
- manpower orientated capacity planning.

TPS output is a detailed production plan, detailed on minute base over the entire planning horizon, combined with a BI (OLAP-) reporting system. Output can be sent to every ERP host system. The run time with thousands of factory orders takes

less than 10 min. TPS is no black box. Every calculation step of every TPS run is recorded and is understandable in detail by the user.

A big advantage of TPS is its usability for strategic simulations. TPS can be considered to be the total simulation model of the company's production. It is impossible to optimize all the concurring production objectives on every level all the time. Solutions only can be satisfying in total. Strategies with the emphasis to individual objectives can easily be executed by changing or adding some TPS parameters. Thus strategies to be simulated for example could be: increase or reduce capacity availability by a multiple of different activities; consequences of any alteration of a product program; absolute emphasis on delivery on time for every customer order; reducing production costs by alternative lot sizes and/or extremely set up decisions; reducing lead time through overlapping production.

The author is convinced that applying Rolling Detail Planning in combination with TPS is able to avoid or at least to minimize the above described weaknesses of ERP solutions and of all APS, which are based on OR methods. But he also is convinced that the ERP vendors, the scientific OR community, and most ERP users and their specialists will defend their crutches violently, some of them are even gold plated.

5 Conclusion

Oliver W. Wright's vision in 1981 of MRP II (closed loop and company game plan) up to now is absolutely insufficient fulfilled by ERP-IT-solutions.

Due to limited IT-capacities in the 1980s production planning process was divided into two levels—rough cut planning and short-time fine tuning. This causes some severe planning weaknesses, which actually are ignored, or forgotten, or hidden, but until now not solved by ERP-solutions.

Main reasons for ERP planning weaknesses and faults are:

- insufficient consideration of capacity constraints
- backward scheduling
- rough cut planning
- missing of applicable manufacturing priorities
- uncoupling job orders from customer orders

They can be considered as planning knock-out criteria.

Results of ERP planning weaknesses are systematically false calculated due dates (start dates and end dates) for every type of order and each production activity. Answer: numerous partial temporary planning solutions (mainly human interactions).

Until now Advanced Planning Systems only deal with subsets of total PPS. Applied mathematical methods (OR) already are unable to manage the large scale and complexity of data of a midrange manufacturing company.

Since 1981 economical circumstances have changed fundamentally and require a planning paradigm change.

Answer: a holistic production planning system based on Rolling Detail Planning (RDP).

Total Planning System (TPS) is able to fulfil RDP requirements. It is based on heuristic simulation techniques with fuzzy logic. During the last 20 years it was successively developed to an effective and comprehensive ERP-Planning tool, to prevent ERP-planning weaknesses.

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