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Editorial

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Welcome to the 45th CIRP Conference on Manufacturing Systems (45th CIRP CMS 2012).

Our society faces challenges, requiring innovative solutions: Returning to growth and to higher levels of employment, combating climatic changes and using our natural resources more wisely, are grand challenges that also provide powerful opportunities for manufacturing. Economies, around the world, need to move towards strategies based on ***innovation***.

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The papers of this Conference address a wide variety of research topics: Manufacturing processes and systems modeling, simulation and optimization, Nanomanufacturing, Rapid Manufacturing, Novel manufacturing processes for advanced materials, Advanced machine architectures and control technologies, Manufacturing systems planning, control and scheduling, Manufacturing networks, Supply Chain and Global Production Management, e-Manufacturing, Logistics and manufacturing data management, Flexible and reconfigurable manufacturing systems, Lean production, Agile manufacturing for turbulent markets, Adaptive manufacturing Systems, Concurrent Engineering, Quality Engineering, Innovative metrology, Energy-efficient processes and systems, Life cycle design and manufacturing, Virtual reality and manufacturing, Digital manufacturing, Digital Knowledge based tools, Collaborative design, Intelligent manufacturing of smart & new products, Human factors, Manufacturing education and training, Methods & tools for Knowledge Management & skills adaptation.

We wish to acknowledge the members of the International Program Committee for having devoted their time to making this event successful. Finally, we thank YOU for your participation, and hope that you find your interactions with this community to be an enriching experience.

Professor G. Chryssolouris
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Model of a Decision Support System for a Least-Cost and Harmonized Capacity Adjustment in the Short- and Medium-Term Planning Horizon

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Abstract

Because fluctuations in demand will increase in future, producing companies will have to adapt their available capacity regularly, always taking the total production costs into account.
In practice, planning of available capacity is being realised without a comprehensive evaluation of changeover costs of total costs. The aim of the presented approach is to support companies in choosing an adequate strategy for a least-cost and harmonized capacity adjustment in the short- and medium-term planning horizon. This also represents a first step towards a new planning approach, enabling not only the systematic utilization of flexibilities of orders, but also of manufacturing resources.

Keywords: Capacity planing ; Capacity adjustment ; Decision-support system ; Flexibility-options ; Adjustment costs

1. Introduction

Over the last years, high fluctuation in demand forced companies to adjust their capacities gradually. According to many experts, this phenomenon will show a significant increase [1]. Due to increasing globalization of business competition and demand, companies will have to adapt their capacity level to the customer demand more often, while giving full thought to efficient cost structures.

SMEs (=small and medium sized enterprises) in particular are going to face greater challenges, since they are more vulnerable to "cost-pressure", because of their relatively insignificant market-share [2]. In addition, they are strongly limited in taking actions and adjusting a different strategy, due to their narrowed and confined financial and human resources [3]. This hypothesis was confirmed through a survey in machinery and plant engineering industry, conducted and carried out by Grundmann und Reinisch [4].

Since one can expect that fluctuations in demand cannot be levelled totally [5], those turbulences have to be handled somehow [6]. This shows that a continuous adaption of production volume and mix is necessary to fulfil the requirements of the international markets [7].

2. Problem Statement

The capacity adjustment mainly deals with deciding and planning problems which have to consider different adaption strategies on given fluctuations in demand. In practice, capacity planning is supported by IT, whereby ERP-systems (=Enterprise Resource Planning systems) are the most used and common ones. ERP-systems use MRP II (= Manufacturing Resource Planning) Logic, in which under-utilized resources or unfulfilled customer orders are visualized and then manually and iteratively optimized [8]. Therefore, the short and medium term capacity planning strongly depends on the experience and ability of the responsible employees. Hence, the achievement of a global optimum is very unlikely. Furthermore the planning process takes place without the consideration of adjustment costs, and as a result without a total cost analysis. In addition, there is no outline of all possible capacity adjustment measures. To

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find an appropriate solution (a global optimum) under these general conditions, a decision support system for manufacturing companies will be developed.

3. State-of-the-art

3.1. Adjustments related to demand fluctuation

How to react on fluctuations in demand is dependent from different parameters, e.g. storage costs, shelf life of products, accuracy of demand forecasts, liquidity of the company, quantity of product variants, and of course the flexibility of each resource [9]. Therefore, it is obvious that the flexibility of a company is not only a function of its ability to shift working hours, but is influenced by multiple parameters.

Buzacott has listed capacity adjustment measures and points out that each of those depends from its situational applicability for capacity levelling and likewise from the measures' related costs [10], but there is no assistance in choosing the right capacity measure. Other authors [11], [12] define capacity adjustment measures more detailed, but they do not deliver selection criteria as well. In comparison to that, Asl and Ulsoy [13] have presented approaches to the capacity management problem based on Markov decision process and feedback control. In this approaches, the decision process itself is focussed, but neither the calculation of adaption costs and adjustment measures nor a practical application in a decision support system.

The concept of capacity envelopes, which is discussed by many different authors [14-18], seems the most promising approach for defining the ideal capacity adaption strategy. In this concept, the x-axis represents the reaction time or the minimum installation time respectively. The y-axis represents the capacity level and shows especially additional or less capacity caused by a certain adaption measure. By interleaving envelope curves of all possible measures for capacity adjustment of a working system, flexibility profiles can be generated. They show the maximum capacity adjustment ability of a production system, but do not factor the related costs.

The existing scientific literature does not deal with operative short and medium term capacity planning in detail; therefore there is no support for identifying the adaption strategy which causes the lowest overall costs. Although an interesting modelling approach for evaluating capacity flexibilities in uncertain markets was presented by Zaeh and Mueller [19]. This approach focuses on evaluating the configuration of Value Streams by their ability to handle the expected market volatility. Furthermore it calculates which changes in fixed costs or profit occurs if different investment strategies or process changes are applied. Therefore, it can be used as a decision support system in long term capacity planning.

Currently, the medium term capacity planning gets along with capacity corridors. The capacity of a resource can be adjusted within such a corridor; exceeding manufacturing orders are shifted [20]. Furthermore, general selection criteria to adapt capacities to the demand cannot be found. However, Gottschalk [15] claims that a sufficient understanding for flexibility at all production stages and a detailed capacity planning lay a foundation for successful capacity adjustments.

In order to identify the need for capacity adaption, Lödding [16] suggests developing capacity profiles for all relevant resources in a first step. In a second step, the bottleneck-resource can be identified, for which specific measures have to be elaborated and proofed. These measures adapt the previous plan and should finally improve the performance of the total system. Nevertheless, Lödding does not discuss how to choose and evaluate adjustment measures and related costs remain again disregarded. Single [21] describes reaction and action methods for companies as well, which struggle with demand fluctuations. Similar to the bottleneck-search at Lödding [16] he looks for weaknesses, and establishes counter-measures and reaction strategies respectively.

In operational practice, capacity planning is generally done with capacity and PPS (= Production Planning and Scheduling) -software's. They are used for staff planning and complete resource planning and are usually integrated in ERP-systems. Generally, they support the flexibility of companies by considering costs in planning. However, adjustment costs are not observed. Some examples are:

- Production von abas [22].
- Fast/pro [23].
- enviso optiCAP [24].
- GANTTPLAN [25].
- WINLine PROD [26].

SAP APO (Advanced Planning and Optimizer) is the production planning component within the mySAP SCM solution. It is probably the most used planning and optimization tool for customer order processing and therefore a closer look is appropriate. It contains 7 modules, whereby Production Planning and Detailed Scheduling (PP/DS) has the biggest relevance for the topic of this paper. Generally, it delivers feasible schedules, optimizes order sequences under consideration of resource capacities, set-up and delay costs, and also matches customer demand with free capacities along the supply chain. However, capacities are treated as fixed constraints and are only adaptable manually.

4. Aim of this paper

As mentioned in the introduction, increase in demand fluctuations force manufacturing companies to adjust their capacities on a day to day basis. Based on this challenge it is aimed to support companies by developing a decision support system that recommends an appropriate capacity adjustment strategy at optimal cost. This strategy consists of a package of measurements to adjust capacities in the short and medium term planning horizon. In this way it is ensured that the user considers all possible adjustment measures and all flexibility measures are evaluated and compared under total cost aspects. The selection of the appropriate mix of measures is supported by an optimization algorithm.

In the scientific literature capacity balancing is divided into capacity levelling and capacity adjustment. Capacity levelling takes place, at least in the short term planning, prior to capacity adjustments. It represents a first try to adapt the demand to the available production capacity in terms of time, technology and quantity [27-29].

In the following, the solution only concentrates on capacity adjustments and assumes that all possibilities of capacity levelling have been used to full extend. Furthermore, the idea bases on the "new perspective in PPS" [6], while the question is: "What do we have to do in operations – regarding capacities and material availability – to fulfil each order in time?" Hence, the actuating variable in order management is not the order release, but rather the variable level of capacity [30].

5. Solution

Within an internally financed research project, a functional model of a reaction system for capacity adjustment at optimal cost was developed (see fig. 1). The fundamental elements of this system are the following:

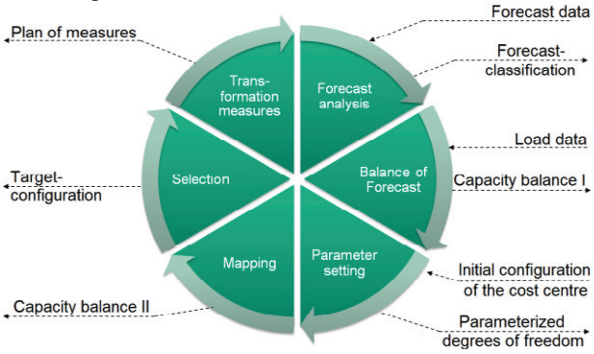

Fig. 1: Model of the reaction system

5.1. Analysing forecast data to identify fluctuation type

At first, forecast data is analyzed and classified in terms of fluctuation. In general, accurate demand forecasts provide the basis for developing a cost-efficient capacity adjustment strategy. It is essential to forecast the trend of demand, but likewise the uncertainty of demand. In literature, forecasting methods are sufficiently discussed [31-33]. To get a valid forecast, it is crucial to use data from different sources, e.g. as cleared and not-cleared production orders, planned orders and long-term forecasts (see Fig. 2:). Demand trends can be classified based on its character (e.g. seasonal fluctuations or peaks) and are relevant indicators for strategic and long term capacity adjustments. [34].

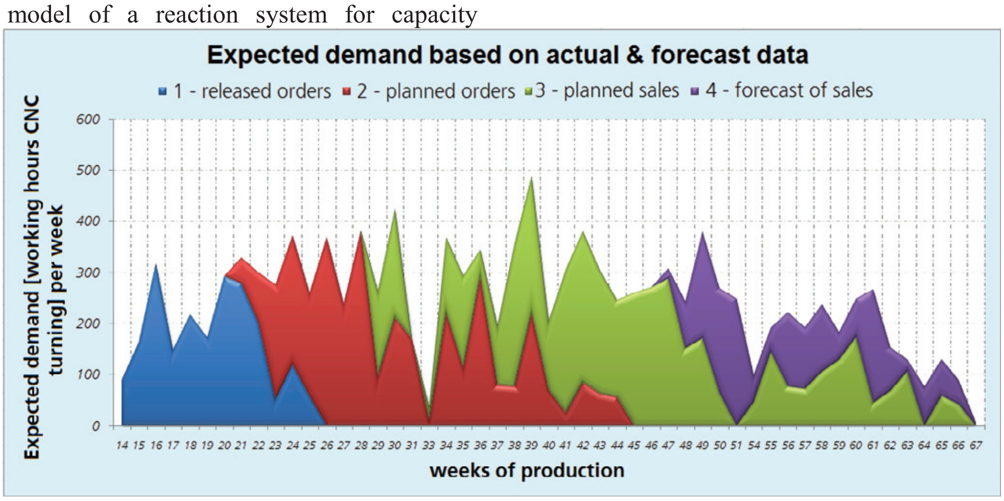

Fig. 2: Overlapping of different types of data-sources

5.2. Comparison of forecast and actual load data with the initial configuration

The comparison of forecast and actual load data with the initial configuration serves as a position check. If there is no deviation between capacity demand and available capacity in the initial configuration, no further measures have to be implemented. If there is deviation in capacity, the next step has to be executed.

5.3. Define and parameterize the degrees of freedom

To conceive and illustrate the flexibility of a resource, it helps to classify the degrees of freedom of a resource in terms of feasible capacity adjustments (see Fig. 3:).

Methods to increase capacity		Methods to reduce capacity	
E 1	Temporary overtime	R 1	Temporary reduction of working hours
E 2	Temporary additional shift	R 2	Shift off / closure days
E 3	Permanent additional shift	R 3	Reduction of employees (direct/indirect)
E 4	Purchase new production facility	R 4	Permanent reduction of shifts
E 5	Increase of working hours in production facility or in administration	R 5	Disinvestment of production facilities
E 6	Increase of efficiency/performance rate of production facilities	R 6	Reduction of efficiency/performance rate of production facilities
E 7	Temporary outsourcing	R 7	Re-insourcing
E 8	Permanent outsourcing	R 8	Adjustment of production processes to reduce capacities
E 9	Adjustment of production processes to support capacities	R 9	Insourcing
E 10	Fully automated shift	R 10	Closing down production facility

Fig. 3: Degrees of freedom in terms of capacity adjustments

In case of application, possible measures for capacity adjustment have to be determined and parameterized appropriately. The relevant parameters are:

Cost aspects	Implementation costs
	Fixed costs per time unit
	Costs per capacity unit
	Costs of capacity reduction
Time aspects	Duration to first employment
	Duration until 100% workload
	max. workload
	min. workload
	Retreat duration to starting level
	Recovery Time
Scale aspects	Max. increase of capacity [total]
	Max. increase of capacity [unit]
	Min. increase of capacity [unit]

Fig. 4: Relevant parameters for a cost-optimal capacity adjustment

5.4. Mapping of demanded and available capacity under consideration of degrees of freedom

The parameters of the previous step can be used for the illustration of capacity envelope curves [14-18]. By overlapping these envelope curves, one can identify a maximum capacity corridor, which outlines the flexibility of this (sub-)system. In this step, capacity is inspected in terms of fulfilment of demand. If the maximum capacity corridor is exceeded or undercut, further measures for capacity adjustments have to be defined. A repetition of step 3 is recommended, to find new or alternative measures for capacity adjustments with a higher impact.

5.5. Selection of the appropriate level of capacity and profile

To reduce costs, an appropriate capacity level will be chosen, whereby a valid measure mix leads to fulfilment in demand. Similar problems have been already solved [35]. However, the larger amount of degrees of freedom requires a new and specific model. For finding a solution, discretisation was executed and all occurring values have been set as steady within a time range. The basic approach is described in the following: For every interval in time Ti,i = 1,…,N and every capacity adaption measure Mk,k = 1,…,R we define a decision variable
X Mki,i = 1,…,N; k = 1,…,R, which states, in which amount the measure Mk in the interval Ti will be started. The definition area Dki of X Mki (e.g. X Mki ∈ {0,1} or X Mki ∈ {0,1,2...} or X Mki ∈ ℝ) results from the nature of the capacity adaption measure Mk.

We combine the variables X Mki,i = 1,…,N; k = 1,…,R to a matrix X. By introducing additional auxiliary variables, we can formulate a linear optimization problem:

Find X in the area D with

$$c * X = \min X \text{ within } D\ c * X \quad (1)$$
$$A * X \leq b \quad (2)$$
$$Aeq * X = beq. \quad (3)$$

The entries of the matrix X evoke certain measures in certain intensity to a certain point of time. c is a cost vector whose values represent the costs for a single capacity unit for each measure. A and Aeq are matrices. The (in)equations (2) and (3) define the acceptable area of the minimizing problem, which results from the restrictions given. Due to the fact that some variables have to be integer, it is a mixed integer linear programming problem.

5.6. Definition of transformation measures

The optimal solution defines the capacity adjustment strategy at optimal cost and delivers a package of capacity adaption measures for each period and resource. Finally, a corresponding action plan has to be worked out and implemented by the responsible.

6. Application Example

In order to evaluate the approach, the cost centre milling of a mechanical engineering company was chosen. According to the approach, described in chapter 5, the forecast-data was analyzed and compared with the initial situation. As no basic trend in the demand has been identified, the possible adjustment measures, the so called degrees of freedom, have been identified and parameterized based on machine hour rate calculations, governmental regulations (maximum overtime and shift models) and outsourcing contracts. The adjustment measures, chosen for further calculations, have been overtime, alternative shift models and outsourcing.

By applying the optimization method as described in chapter 5.5, a capacity adaption strategy was derived. The final level of capacity, which was elaborated considering all given restrictions, is illustrated in **Error! Reference source not found.**. The green dashed line represents the available capacity as a result of the planning process. Due to the given restrictions, many phases with over-capacity occur. It can be assumed, that there is still room for improvement and further adjustment measures have to be considered to be able to adapt to the demand need optimally. These could be under-time or eventually finished goods storage.

7. Summary and prospect

Results so far provide a standardised procedure, including related tools to conceive, to parameterize and to visualize degrees of freedom in terms of capacity adjustments, and consequently a procedure to find a cost-optimal capacity adjustment strategy. The existing weaknesses in the results will be eliminated in the on-going work.

Funding for a research project, in which a fully ERP-integrated decision support system for capacity adjustment will be developed, has just been granted. This decision support system will surpass existing solutions in ERP and MES (=Manufacturing Execution Systems) -systems and improve short and medium term capacity planning.

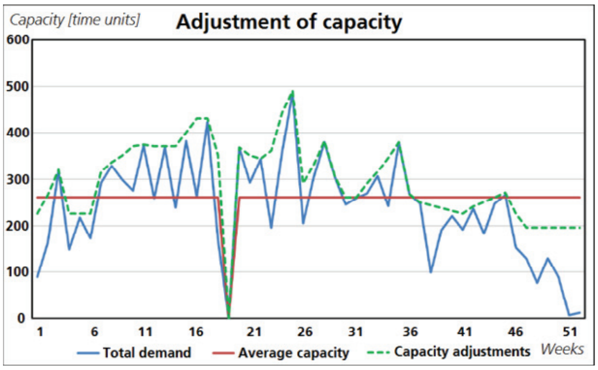

Fig. 5: Level of capacity at minimized costs in the cost centre milling

References

[1] Colombier, C., Geier, A., 2011, Fiskaleinnahmen, Konjunktur und Potenzial-BIP, Die Volkswirtschaft 6/2011.
[2] Gómez Kempf, F.A., Aurich, J.C. Drews, O., 2008, Implementation Strategy for a Flexibility Oriented Production System, Proceedings of the CIRP, 41:315-318.
[3] Abel, J., 2007, Ganzheitliche Geschäftsmodelle in KMU, wt Werkstattstechnik online 97, 4:293-297.
[4] Grundmann, S., Reinsch, S., 2006, Flexible Kapazitäten im Maschinen- und Anlagenbau; Industrie Management, 22/5:42-44.
[5] Buhl, M., Deuse, J., 2009, Stufenmodell zur Nivellierung in der variantenreichen Kleinserienfertigung, PPS Management, 14/2:26-29
[6] Wiendahl, H.-H., 2002, Situative Konfiguration des Auftragsmanagements im turbulenten Umfeld, Dissertation, University Stuttgart
[7] Günthner, W.A., 2007, Neue Wege in der Automobillogistik, die Vision der Supra-Adaptivität; Springer, München, 1:41.
[8] Dickmann, P., 2007, Schlanker Materialfluss mit Lean Production, Kanban und Innovationen, Springer, Grafing, 1:326.
[9] Gotzel, C., 2010, MRP zur Materialplanung für Kreislaufprozesse, Wiesbaden
[10] Buzacott, J.A., Corsten, H., Gössinger, R., Schneider, H.M., 2010, Produktionsplanung und -steuerung, Grundlagen, Konzepte und integrative Entwicklungen, Oldenbourg, 1:104 ff.
[11] Wannenwetsch, H., 2007, Integrierte Materialwirtschaft und Logistik – Beschaffung, Logistik, Materialwirtschaft und Produktion, Springer, Berlin, 3:479.
[12] Hachtel, G., Holzbaur, U., 2010, Management für Ingenieure – Technisches Management für Ingenieure in Produktion und Logistik, Vieweg+Teubner, Wiesbaden, 1:104.
[13] Asl, F.M., Ulsoy, A.G., Stochastic optimal capacity management in Reconfigurable Manufacturing Systems. Annals CIRP, 2003, 52, 371–374.
[14] Wiendahl, H.-P., Breithaupt, J.-W., 1998, Kapazitätshüllkurven - Darstellung flexibler Kapazitäten mit einem einfachen Beschreibungsmodell, Industrie Management, 14/4:34-37
[15] Gottschalk, L., 2005, Flexibilitätsprofile: Analyse und Konfiguration von Strategien zur Kapazitätsanpassung in der industriellen Produktion, Dissertation, ETH Zürich
[16] Lödding, H., 2008, Verfahren der Fertigungssteuerung, Springer, Dülmen, 2:467-478.
[17] Reinhart, G., Schellmann, H., 2009, Rahmenkonzept zur Ermittlung kundenspezifischer Mengenflexibilität, ZWF 104/7-8:546-551.
[18] Bornhäuser, M., 2009, Reifegradbasierte Werkstattsteuerung; Dissertation, University Stuttgart, :87.
[19] Zaeh M. F.,Mueller N., 2007, A modeling approach for evaluating capacity flexibilities in uncertain markets, Int J Flex Manuf Syst 19:151–172.

[20] Kurbel, K., 2011, Enterprise Resource Planning und Supply Chain Management in der Industrie, Oldenbourg, München, 7:146 ff.
[21] Single, N., 2010, Methodik zur Identifikation von Reaktions- und Handlungsmöglichkeiten auf kundenseitige Auftragsschwankungen, diploma thesis, University Karlsruhe, 1:28 ff., :73 ff., :86 ff.
[22] http://www.abas.de/de/erp/fertigung.htm, and http://www.abas.de/de/download/abas_erp/erp-pps-fertigung.pdf, 07.09.2011, 1:14 f.
[23] http://www.lis-logistik.de/de/methoden-und-produkte/produktionscontrolling/, 06.09.2011.
[24] http://www.softguide.de/prog_h/ph_1938.htm, 05.09.2011.
[25] http://www.sage.de/partnerloesungen/P813/info-ganttplan-0501.pdf, 05.09.2011
[26] http://www.softguide.de/prog_f/pf_0299.htm, 05.09.2011
[27] Arnold, D., Isermann, H., Kuhn, A., Tempelmeier, H., Furmans, K., 2008, Handbuch Logistik, Springer, Berlin, 3:331 f.
[28] Sihn, W. et al., 2010, Grundlagen des Produktionsmanagements, Skriptum zur Unterstützung der Vorlesung Produktionsmanagement, Vienna, 5:90f.
[29] Schuh, G., July 2011, Produktionsmanagement I - Unterlagen zur Vorlesung, http://www.wzl.rwth-aachen.de/de/080d8d8c949a1ac0c1256f190035d886/pm_1_v07.pdf
[30] Reinhart, G., Dürrschmidt, S., Krüger, A., 2009, Stückzahlflexible Montage- und Logistiksysteme, wt Werkstattstechnik 89/9.
[31] Armstrong, J., 2001, Principles of Forecasting - a handbook for researchers and practicioners, Springer.
[32] Morrell, J., 2001, How to forecast - a guide for business; Gower Publishing Ltd.
[33] Thonemann, U., 2010, Operations Management, Konzepte, Methoden und Anwendungen, Pearson Studium, Munich, 2
[34] Fandel, G., Giese, A., Raubenheimer, H., 2009, Supply Chain Management, Strategien - Planungsansätze – Controlling, Springer, Berlin, 1:149-176.
[35] Stephan, A., Fischer, O., 2001, Betriebswirtschaftliche Optimierung – Einführung in die quantitative Betriebswirtschaftslehre, Oldenbourg, 6:216-212