MALZEME İHTİYAÇ PLANLAMASI ORTAMINDA PLANLAMA SİSTEMLERİNİN KARARSIZLIĞI ÜZERİNE GÖZDEN GEÇİRME

K. Erkan KABAK
Dokuz Eylül Üniversitesi, Endüstri Mühendisliği Bölümü, Bornova, 35100, İzmir.

Arslan M. ÖRNEK
Dokuz Eylül Üniversitesi, Endüstri Mühendisliği Bölümü, Bornova, 35100, İzmir.

Özet: Malzeme ihtiyaç planlamasında, talepten ve kaynak tedariğinden kaynaklanan bilinmezlikler malzeme planlarında bozulmalara ve planlarının sık sık revize edilmesine neden olur. Bundan dolayı, stabil bir üretim planlamasının yürütülmesi önemli bir konu olarak karşımıza çıkar.

Stabil bir üretim planı, üretim planına ek ihtiyaçlar girdikçe zamanla sık değişmeyen bir plandır. Stabilitenin yanında, stabilite ile ilgili başka kavramlar da vardır. Esneklik (flexibility), planlama sistemlerinin beklenmeyen değişikliklere cevap verebilme yeteneği olarak tanımlanır. Robustness (planların kuvveti), üretim kararlarının ve planlama yöntemlerinin girdilerdeki değişikliklere duyarsızlığıdır.

Müşteri siparişlerinin, değişen satış tahminlerinin, üretim planlarının değişmesinden veya beklenmeyen tedarikçi ve üretim problemlerinden kaynaklanarak üretim planlarına yapılan değişiklikler, üretim ve envanter maliyetlerinin artmasına, kapasite kullanımında azalışa ve müşteri servis seviyesinin bozulmasına neden olur. - Planlamada bu olguya “sinirlilik” (Nervousness) adı verilir.

Bu faktörlerin ölçümü, üretim planlarının farklı işlem koşullarında yürütülmesi için değişik yöntemlerin performanslarının karşılaştırılmasına olanak verecektir.

Bu bildiride , üretim planlarının kararlılığı üzerine değişik işlem koşullarında yapılan geçmiş çalışmalar, bu çalışmalarda yer alan stabilite ölçüm yöntemleri, karar değişkenleri, bu değişkenlerin planların kararlılığı üzerine etkisi çalışmalarda bulunan sonuçlarla karşılaştırılmış ve son olarakta planlamanın kararsızlığı ve üretim planlarındaki sinirliliği (nervousness) azaltan yöntemler gözden geçirilmiştir.

Anahtar Kelimeler: *üretim planlama kararsızlığı; MİP; sinirlilik*

A REVIEW OF INSTABILITY OF PLANNING SYSTEMS IN A MATERIAL REQUIREMENTS PLANNING ENVIRONMENT

Abstract: *Uncertainties in demand and supply lead to disruptions in material planning and frequent plan revisions. Maintaining a stable production plan is an important competitive factor in material requirements planning system.*

A stable schedule is one that does not often change with time as additional requirements data are added to the planning horizon. Besides stability, there are other stability-related concepts to evaluate the sensivity of planning methods e.g., flexibility and robustness.

Frequent adjustments to schedules caused by customer order changes, varying sales forecasts and production plans or unforseen supplier and production problems can lead to increases in throughput times, inventories, production and inventory costs, decrease capacity utilization and a deterioration in customer service levels - This phenomenon in literature is referred to as Nervousness.

Measurement of instability would enable performance comparison of different planning procedures for managing the production plans under a variety of operating conditions.

This paper is a review which examines the previous research on planning stability under different operating conditions, stability measuring metrics, decision variables, the effects of these variables on schedules' stability by comparing the results between them and finally it will present strategies to dampen nervousness and decrease instability.

Keywords*: scheduling instability; MRP; nervousness; planning horizon*

1. INTRODUCTION

In Material Requirements Planning (MRP) environment, master production scheduling (MPS) and material planning are the major components of the manufacturing planning and control systems and play a vital role by providing the key link between front-end production plans – resource planning, production planning, demand management – and the shop-floor, vendor systems (Vollman et al, 1997), so that the development of an effective MPS system and material planning are frequently cited as critical elements in obtaining full benefits of and managing effectively with MRP. Yet, they are frequently unrealistic and out of step with available material and actual capacity, because different sources of uncertainties exist in the material planning system.

Generally, uncertainty is referred to as the probability that the realization will differ from the expectations or estimates. There are various classifications dealing directly with the uncertainties. First of them defines uncertainties as primary and secondary; primary uncertainties take place from an external source, and cause to change the available information. The latter occurs as a consequence of primary uncertainties. They also may be further classified into vertical and horizontal uncertainties. Second classification relates to the distinction in timing and in quantity; timing uncertainty occurs later or earlier than expected and frequently leads to important problems in the execution of the planning systems, but quantity uncertainty defines the extent to which the realization differs from its expectation (Heisig, 2002). The final classification concerns directly with the uncertainties and looks into their sources in a production environment. Since such an environment consists of customers, suppliers and the production system itself, they are further classified as, namely, uncertainties in demand and supply, and stochastic influences in the production system itself. For example, customer orders may be cancelled, increased or decreased, unexpected scrap or machine breakdowns may occur and materials may not be delivered in time or may not be in the right quality or quantity.

Due to these uncertainties and their effect on operational planning, planning systems and decisions are frequently reviewed and updated with respect to the actual developments in the environment. Conventionally, a rolling horizon schedule and safety stocks or safety times are usually applied as means to overcome uncertainties.

In Section 2 of this paper we define the concepts related to uncertainty, namely flexibility, robustness, nervousness and planning instability. Then we review methods used to measure planning instability in Section 3. After measuring instability we present strategies developed to dampen nervousness in MRP environment. Finally we comment on the techniques employed to measure and dampen nervousness and present pros and cons of these methods.

2. CONCEPTS RELATED TO UNCERTAINTY

2.1 FLEXIBILITY AND ROBUSTNESS

The operating flexibility is another way of protection against uncertainties. It means that some necessary actions are performed and internal processes are accelerated to tackle with the uncertainties caused by the external sources in emergency situations. Generally, the ability of a system to respond to unexpected situations is defined as "flexibility" and it comes out as an important competitiveness factor for companies as the speed of the information flow increases. However, the flexibility of a planning system is a more general term and implies that the system's capability to adjust to the development of all possible situations. It includes both responsiveness and ability to tackle with the uncertainties in the planning environment.

In connection with the flexibility, robustness is usually considered. Heisig (2002) defines robustness as the invariability of initial decisions, or the persistence of complete decision sequence. However, from the planning point of view, it is understood as the insensitivity of the planning systems when the parameters change in stochastic input data.

Both flexibility and robustness are concepts to determine the sensitivity of planning systems. While comparing these terms, robustness may be evaluated as a specific measure of flexibility. Because it just implies the insensitivity of a system in stochastic input data but flexibility also includes the dynamic nature of the environment.

2.2 NERVOUSNESS

Besides flexibility and robustness, there is another term related with the sensitivity of planning systems: "nervousness". It is a common problem which results when using MRP systems and is defined in literature in several ways. The term was coined by Steele (1973), and he used it to refer to the changes which take place in a schedule when the horizon is rolled forward. He identifies some of the causes of nervousness as unanticipated master schedule changes due to the updated forecasts, releasing planned orders prematurely or in an unplanned quantity, not issuing the allocation in expected quantity, and changes in MRP system parameters such as lot size, safety stock, or lead time.

Vollmann (1997) defines nervousness shortly as significant changes in MRP plans, which occur even with only minor changes in higher-level MRP records or the MPS and notes that the distinction between nervousness in the MRP plans and nervousness in the execution of MRP system plans. Nervousness in the execution of the plans may also affect the behaviour of the planning system.

Since the causes of nervousness are customer order changes, varying sales forecasts and production plans or unforseen supplier and production problems, they can lead to frequent adjustments in schedules and result in increased throughput times, inventories, production and inventory costs, decreased customer service levels, capacity utilization. Furthermore, the frequent schedule changes cause to loss of confidence towards the planning system and create the confusion on the shopfloor. Actually this phenomenon is referred to as "nervousness" in studies of Kadipasaoglu (1997), Sridharan (1987, 1988, 1990, 1994) and Zhao (1997, 2001, 2003). Due to this importance of nervousness, it is taken as a decision variable with the total system cost and service level and is measured taking into account rolling horizon parameters: the length of planning horizon, the rolling interval length, freeze interval length and some environmental factors such as lumpiness factor, coefficient of variation, natural cycle, lot sizing rule, etc.

2.3 PLANNING INSTABILITY

In some definitions, it is clear that there is a close relationship between the terms nervousness and instability. For instance, Blackburn et al. (1986) considers MRP system nervousness as "instability in planned orders" caused by uncertainty in demand and variations in lot-sizing decisions. Furthermore, Silver et al. (1998) define nervousness as "instability in MRP systems" and point out that it specifically refers to frequent scheduling actions, such as expediting, delaying or canceling an order, or to changing the size of an order.

However, in literature different definitions of stability are used and schedule instability or stability terms are faced frequently to imply that the nervousness in MRP plans. For example, Sridharan et al. (1988) defines a stable schedule as one that does not change with time as additional requirements are added to the planning horizon. He notes that such a stability measure would enable a performance comparison of different procedures for managing the MPS under a variety of operating conditions. In addition, it may be easier to measure schedule instability in constructing the measure. Furthermore, Inmand and Gonsalvez (1997) define a schedule as stable "if the production requirement forecasts for a given period do not change and equal the actual production requirements for that planning period". Instability is usually amplified from one supplier to the succeeding supplier. Actually according to them, stability implies a given production plan will be followed, whereas instability means not following the plan.

With regard to the supply chain management (SCM), Heisig (2002) states that one of the most important enablers for efficient supply chain operations is schedule stability. Moreover, in a Just-in Time (JIT) environment, it causes significant problems for suppliers.

Heisig (2000) defines the planning stability in order to determine and compare the stability performance of different lot-sizing rules in subsequent planning cycles of a rolling horizon schedule as follows: "The planning stability of a decision rule or planning method is represented by the extent to which decisions for a certain time period and planning cycle remain unchanged for the same time period in subsequent planning cycle".

In summary the term "planning instability" or "lack of planning stability" must be defined more clearly and should be in such a measurable format that performances of different procedures could be easily compared. For this purpose, the following section presents different measuring metrics.

3. MEASUREMENT OF INSTABILITY

In literature, only little work has been done in developing and defining applicable measures of instability so far. As in Kok and Inderfurth (1997) only ad-hoc measures of instability are used in a wide set of simulation studies. A systematic discussion of instability measures is found in Sridharan et al. (1988), Kadipasaoglu and Sridharan (1996), Kimms (1998), Kok and Inderfurth (1997), Jensen (1993) and Heisig (2002).

One of the earlier studies to measure the instability in literature is encountered in the paper of Blackburn et al. (1986), which defines instability as the number of times an unplanned order is made in the first period when the schedule is rolled forward. They count the number of times that changes take place in the imminent period of the planning horizon. However, their measure has some problems: Firstly, it depends on enumeration and as the planning horizon length increases, it quickly approaches the desired value of zero, i.e., as the horizon length is increased, instability artificially is reduced. In addition, although the changes in the immediate period are relatively more critical, it fails to assess changes in open orders within the cumulative lead time. Thus, considering only the immediate period schedule changes is not adequate. Also, in their study it is assumed that demand was deterministic and lead times were zero, therefore the need for open order rescheduling is questionable. Finally, their measure is not in the analytical format and does not classify the different kind of changes in the immediate period.

Sridharan et al. (1988) suggest an alternative measure of instability that includes the weighted average of schedule changes in order quantity per order over subsequent planning cycles, i.e.

$$I_{SBU} = \frac{\sum_{\forall k>1} \sum_{t=M_k}^{M_{k-1}+N-1} \left| Q_t^k - Q_t^{k-1} \right| (1-\alpha)\alpha^{t-M_k}}{S} \qquad (1.1)$$

where

t = time period,

Q_t^k = scheduled order quantity for period t during planned cycle k,

M_k = beginning planning cycle k,

N = planning horizon length,

S = total number of orders over all planning cycles, and

α = a weight parameter to represent the criticality of changes in schedule ($0< \alpha <1$)

Furthermore, they suggest relating the measure in (1.1) to the average lot size and the MPS instability measure (I_{SBU}) can be stated in terms of the proportion of an average MPS order that is changed (A). As approximating for this average they use the well-known Economic Order Quantity (EOQ) formula. The modified nervousness measure is then given as

$$A = \frac{I_{SBU}}{EOQ} \qquad (1.2)$$

This standardized measure is based on the assumption that the average order cycle, or natural cycle (T), is equal to the ratio of the EOQ and average or expected period requirements (R), respectively, i.e.

$$T = \frac{EOQ}{R} \qquad (1.3)$$

In this metric, what is different from that of Blackburn's is that a weighting procedure is applied to schedule changes; decreasing weights are used to represent the increased ability to respond increasing uncertainty of demands. Another difference is the weights can be varied, for example a small value for the weighting parameter α (i.e., a value close to zero) can be placed for rapidly decreasing weights to changes in future periods, whereas a larger value for α (i.e., a value close to one) can be placed for nearly equal weights to changes in all future periods, so that the instability measure could be adjusted to reflect the importance of the immediate future.

However, the metric has some shortcomings; Firstly, the single-level product structure, i.e., this measure of instability is intended for single-item, single-level situations, but the components at lower levels must also be considered since their schedules can significantly impact both material and capacity plans. In addition, rescheduling open orders at the top level and then updating the MRP plans is likely to change the quantity and/or the timing of planned orders within the cumulative lead time. The changes in planned orders at the top level of the product structure may cause rescheduling of open orders at the lower levels. Also, there is no distinction between changes in setup decisions and changes in quantities. Thus, it specifically takes into account the timing by weighing changes occuring in different periods. Furthermore, the instability measure is not normalized between values of 0 and 1, i.e., maximum stability and maximum instability as well as A in (1.2). Also note that, this metric measures instability as "weighted instability per order" and it is biased because number of orders depends on the cost structure of the item, and on the ratio between the setup cost and the holding cost. Since the EOQ depends on the inventory holding and setup costs, so, the same is valid for A. Finally, the weights used in the numerator of (1.2) are period-specific, whereas in the denominator the value is an average or expected period requirements.

Kadipasaoglu and Sridharan (1996) have extended the previous instability measure I_{SBU} in (1.1) and eliminated some shortcomings of it by adding a weight parameter β to assign decreasing weights to the changes in subsequent levels of the product structure. Like α, a small value of β assigns rapidly declining weights, large value of β assigns slowly declining weights. This metric defines instability as the weighted change in order quantities for all items at all levels through the subsequent planning cycles as follows:

$$I_{KS} = \sum_{\forall k>1} \sum_{j=0}^{m} \left[\sum_{i=1}^{n_j} \sum_{t=m_k}^{M_{k-1}+N-1} \left| Q_{ijt}^{k} - Q_{ijt}^{k-1} \right| (1-\alpha) \alpha^{t-M_k} \right] (1-\beta)\beta^{j}, \qquad (1.4)$$

where

j = item level, $j = 0,\ldots,m$ (based on low level coding),
i = item i at level j, $i = 0,\ldots,n_j$,
t = time period,
N = planning horizon length,
k = planning cycle,
M_k = beginning period of planning cycle k,
Q_{ijt}^{k} = order quantity (open and/or planned) for item i at level j in period t as planned in cycle k,
α = weight parameter for periods, ($0< \alpha <1$) and
b = weight parameter for levels ($0< b <1$),

Contrary to I_{SBU}, this measure does not divide the total instability by the number of planned orders over all planning periods. Therefore, the bias is avoided, and it is not biased by the cost structure of the product. Due to the level-weight parameter β, different weights to items at different stages in the product structure can be assigned.

However, among these advantages of this metric, the major deficiency of it is that it is still not standardized between a minimum and maximum value of nervousness. So, it does not permit the comparison of the different scenarios. In addition, different kinds of change are not still differentiated; for example, the weights for the setup and quantity changes are the same.

Unahabhokha et al. (2002) use a version of the stability measurement model presented by Sridharan et al. (1988), The measure is:

$$I_U = k \sum \sum W_t \left| Q_{i,t}^{p2} - Q_{i,t}^{p1} \right| / B \qquad (1.5)$$

where:

i = item number,
t = time period, weeks,
n = total number of products, $n = 1,\ldots,22$
H = planning horizon length, $H = 1,\ldots,52$
$Q_{i,t}^{p2}$ = scheduled production for item i, period t, during planning cycle 2,
$Q_{i,t}^{p1}$ = scheduled production for item i, period t, during planning cycle 1,
B = total production for planning cycle 2,
k = multiple factor,
W_t = weighting factor, $Exp(1/t)-1$,

This measure is rather similar to the measure presented by Sridharan et al. (1988), a multiple factor, k, used to amplify the result and weighting factor, W_t, is incorporated in this measure due to the fact that the impact of schedule instability is not necessarily linear through time. However, it includes all the shortcomings mentioned for the (1.1).

Kimms (1998) discusses several production planning problems for which decisions are to be made on a rolling horizon basis that range from capacity expansion planning to master production scheduling and to lot sizing. He considers a T-period problem on the MPS level which is rolled $n > 0$ times and as different from other measures, he adds a frozen zone in the rolling horizon schedule. Also, for two subsequent planning cycles i and $i-1$ instability is compared. This creates a production plan for the periods $(n-1)\Delta T+T$ where ΔT represents the length of frozen zone. In each run $i = 1,\ldots,n-1$ the plan for the periods $(i-1)\Delta T+1,\ldots,i\Delta T$ is implemented while the plan for the periods $i\Delta T+1,\ldots,(i-1)\Delta T+T$ is of a preliminary nature. Then, Kimms presents the instability measure with respect to the production plan of item $j (j = 1,\ldots,J)$ as

$$I_{KI}^{j}(i) = \frac{\left| q_j^{\cdot\cdot(i)} - q_j^{\cdot(i-1)} \right|}{\max\{q_j^{\cdot\cdot(i)}, 1\}} \qquad (1.6)$$

where
i = number of run, $i \geq 2$,

$q_j^{\cdot i} = \sum_{t=1}^{T-\Delta T} \zeta_{jt} q_{j(t+i\Delta T)}$ for $i = 1,\ldots,n-1$, (weighted production quantities for item j, temporarily scheduled),

$q_j^{\cdot\cdot i} = \sum_{t=1}^{T-\Delta T} \zeta_{jt} q_{j(t+(i-1)\Delta T)}$ for $i = 2,\ldots,n-1$, (weighted production quantities for item j, after rescheduling in overlapping periods),

q_{jt} = production quantity for item j in period t $(j = 1,\ldots,J; t = 1,\ldots T-\Delta T)$,

ζ_{jt} = item-specific weights for item j in period t $(j = 1,\ldots,J; t = 1,\ldots T-\Delta T)$,

Kimms notes that the item-specific weights should be positive and non-increasing over time and proposes the use of item-independent weights. For example,

$$\zeta_{jt} = \frac{1}{t} \qquad (1.7)$$

for $(j = 1,\ldots,J$ and $t = 1,\ldots,T-\Delta T)$, which is item-independent and so it expresses that there is no preference for keeping the schedule more stable for some items than for some others.

Kimms also considers several alternatives to measure the instability of the overall plan

$$I_{KI}^{\max}(i) = \max\{I_{KI}^{j}(i) \mid j = 1,\ldots J\} \qquad (1.8)$$

represents the maximum instability, and

$$I_{KI}^{mean}(i) = \frac{1}{J}\sum_{j=1}^{J} I_{KI}^{j}(i) \qquad (1.9)$$

describes the mean instability. In all cases, a value close to zero indicates good performance. If $\Delta T = T$ would be chosen, there would be no instability at all.

When we evaluate the Kimms's measure, firstly, frozen period ΔT is considered, and to calculate the instability the differences are taken before and after rescheduling. Also, the weighted production quantities are used and the weights are integrated into the equation so that the impact of the time according to rescheduling can be integrated more accurately. In addition, Kimms gives a different weight parameter, it is item independent but this weight can not be varied as Sridharan's parameter α does. In another point of view, only the end item level is considered, but the components at lower levels also must be considered since their schedules can significantly impact both material and capacity plans. Moreover, from the standardization point, although the differences in quantities are divided by a maximum in the equation, Kimms' measure can take on values greater than 1.

Kok and Inderfurth (1997) treat planning instability as a specific criterion and investigate how it is affected by different inventory control rules. They define the planning instability more precisely and state that the most serious changes in the planning process are faced when the actual order releases deviate from the planned orders determined in the previous cycle. So, they separate according to this matter the short-term planning stability with long-term stability. Furthermore, stability examined on the aspect of pure qualitative changes or quantitative changes of order decisions. A qualitative replanning action considered to occur when a planned production setup is canceled in a new planning cycle or if, vice versa, a new setup is changed. This effect is denoted as setup-oriented stability. Quantity-oriented stability is considered when the deviations in the order quantities of successive planning cycles are of relevance. While taking them into account, they use the measurement concept proposed in Jensen (1993) where instability is measured by the ratio of expected (quantity or setup) deviations of orders over the expectation of maximum deviations that can take place under worst case inventory control as (Kok and Inderfurth, 1997);

Setup stability is measured by

$$I_s = 1 - \frac{E\left[\left|\delta(Q_1) - \delta(\hat{Q}_1)\right|\right]}{\max_{\Re, F_D} E\left[\left|\delta(Q_1) - \delta(\hat{Q}_1)\right|\right]}, \qquad (2.0)$$

where

$E[\cdot] =$ the expected value,

$\Re$ = stationary inventory control rule,

F_D = cumulative demand function with a stochastic *iid* demand D,

$\delta(Q) = 1$ for $Q > 0$, $\delta(Q) = 1$ for $Q = 0$,

Quantity stability is formulated by

$$I_q = 1 - \frac{E\left[\left|Q_1 - \hat{Q}_1\right|\right]}{\max_{\Re, F_D} E\left[\left|Q_1 - \hat{Q}_1\right|\right]}, \qquad (2.1)$$

It is clear that both stability measures are normalized to values between zero and one so that each decision rule $\Re$ with any set of parameters can be compared in a meaningful way when using these measures. In the interpretation of the measure I_s; $I_s = 0$ means that a decision rule causes complete (i.e., maximum) nervousness while $I_s = 1$ is equal to the situation of complete planing stability. However, the measures in (2.0) and (2.1) are restricted to planned order deviations only referring to the most imminent period in each planning cycle, as also they stated it describes short-term stability and also it lacks of the impact of multi-item at different levels in the product structure.

Heisig (2002) proposes the modified setup instability as follows:

$$I_{Hs} = \frac{\sum_{j=1}^{N-1} \sum_{i=j}^{P+j-2} \left| \delta(q_{t+i}^{t+i-1}) - \delta(q_{t+i}^{t+i}) \right| (1-a) a^{i-j}}{(N-1) \sum_{t=1}^{P-1} (1-a) a^{t-1}} \qquad (2.2)$$

As can be seen that it is similar to the measure presented by Sridharan et al. (1988). In this measure, the weighted number of periods with changed setups are divided to the weighted total number of periods, and it is normalized between zero and one. Maximum instability occurs when the $I_{Hs} = 1$, and when it equals zero, maximum stability is achieved.

Heisig (2002) takes the limit of the measure in (2.2) with $a \rightarrow 1$ and gives $P = 2$, and measures the instability as all periods are weighted equally and gets the measure according to the first period's replenishment decision as follows;

$$I_{Hs} = \frac{\sum_{j=1}^{N-1} \left| \delta(q_{t+i}^{t+i-1}) - \delta(q_{t+i}^{t+i}) \right|}{(N-1)} \qquad (2.3)$$

This measure reflects that the plan changes directly affect the shopfloor and planned setup in the first period of a planning cycle is taken placed immediately in the next planning cycle.

Similar to the setup-oriented instability, Heisig (2002) gives quantity-oriented instability by

$$I_{Hq} = \frac{\sum_{j=1}^{N-1} \sum_{i=j}^{P+j-2} \left| \delta(q_{t+i}^{t+i-1}) - \delta(q_{t+i}^{t+i}) \right| a^{i-j}}{\Delta q_{\max}} \qquad (2.4)$$

In this measure in (2.4) the weighted average percentage of quantity per cycle is divided by the weighted maximum possible amount of changes per planning cycle. However, in this measure the calculation of the maximum quantity is some difficult and requires some additional assumptions. A maximum reasonable demand per period is assumed, D_{max} and taking into account the also the first period's backorders Δq_{max} is calculated as

$$\Delta q_{\max} = \left(2 \sum_{t=1}^{P-1} a^{t-1} + 1 \right) D_{\max}$$

4. STRATEGIES TO DAMPEN INSTABILITY IN MRP SYSTEMS

Several different strategies have been suggested for dealing with instability in MRP systems in the literature. Blackburn et al. (1986) proposed and investigated five different strategies for treating instability caused by the interaction of lot-sizing decisions and the planning horizon under deterministic demand The five strategies examined are:

(1) Freezing the schedule within the planning horizon,

(2) Lot-for Lot after stage 1,
(3) Safety stocks,
(4) Forecast beyond planning horizon,
(5) Change cost procedure.

Among these strategies in terms of instability reduction, the results indicate that when the source of instability is due to changes in decisions caused by a rolling planning horizon, safety stock and lot-for-lot strategies are not cost effective and when measured solely in terms of instability, freezing the schedule within the planning horizon appears to be dominant.

Vollmann et al (1997) introduces three guidelines reducing instability in MRP plans:
(1) Freezing and time fences
(2) Selective use of lot-sizing procedures and
(3) Using firm planned orders

Heisig (2002) provides a more detailed overview of procedures for reducing instability as identified in literature in Table 1.

Table 1**.** Overview of methods for reducing nervousness

Orientation	**Methods**
Lot-sizing	"stable" lot sizing rules
Inventory-oriented buffering	Safety stock Safety lead time Safety capacity Overplanning
Eliminating causes of nervousness	Rolling horizon schedule parameters (e.g. freeze MPS) Forecasting beyond planning horizon Control engineering changes Eliminate transaction errors Minimize supply uncertainty
Local-oriented	Demand management Time-fencing Lead-time compression Pegged requirements Firm planned orders
Dampening procedures	Static dampening procedure Automatic rescheduling procedure Cost-based dampening procedure

It is observed that freezing a portion of the schedule, especially over the cumulative lead time of a product, is the most used approach in recent studies. In studies of Sridharan (1987, 1988, 1990, and 1994), the impact of freezing on total cost, instability and fill rate is examined in the single-item, single-level, no capacity constraint and deterministic, stochastic demand conditions. The results indicate that instability decreases as the freezing proportion increases but this effect makes the costs get increase and causes no major loss in service level in deterministic demand conditions. However, under stochastic demand condition, the use of longer planning horizon appears to increase the cost error in contrast to the deterministic demand case. In addition, Sridharan (1987) proposes two methods of freezing, namely, period based freezing and order based freezing and suggest that an order based freezing method produces superior results in comparison with the period based method. Additionally, in the studies of Zhao (1997, 2001 and 2003), the impact of selection of lot-sizing rules and selection of the parameters for freezing the MPS on instability are investigated under multi-item, multi-level, capacity constraint conditions. With regard to the three main decision variables ~~view~~, ie, total cost, schedule instability and service level, Table 2 summarizes the findings under different conditions while increasing the rolling horizon parameters.

Table 2. Summary of findings on the Impact of Freezing Parameters

Authors (year)	Settings	Planning ⇑ Horizon (PH)	Freezing ⇑ Proportion(F)	Replanning ⇑ Periodicity
Sridharan, Berry, and Udayabhanu (1987)	Deterministic Single-item No capacity const.	TC ⇓ [a]	TC ⇑	N/A[a]
Sridharan, Berry, and Udayabhanu (1988)	Deterministic Single-item No capacity const.	SI ⇑ and than levels off	SI ⇓	N/A
Sridharan And Berry (1990)	Stochastic Single-item No capacity const.	Cost of error ⇑ SI ⇑	Cost of error ⇑ SI ⇓	TC ⇓ SI ⇓
Sridharan And Lafarge (1994)	Stochastic Single-item No capacity const.	N/A	inventory ⇑ No major loss in SL	N/A
Zhao et al. (2001)	Deterministic Multi-item CapacityConstraint	TC ⇓ SI ⇑ SL ⇑	TC ⇑ SI ⇓ SL ⇓	TC ⇓ SI ⇓ SL ⇑
Xie, Zhao and Lee (2003)	Stochastic Multi-item CapacityConstraint	TC ⇓ SI ⇓ SL ⇑	TC ⇑ ⇓ SI ⇓ SL ⇓ ⇑	TC ⇓ SI ⇓ SL ⇑

[a] "⇑ " means " increase, "⇓ " means " decrease, and "N/A" means " not applicable".

5. CONCLUSION

In this review, we tried to explain the concepts related uncertainty, i.e., flexibility, robustness and nervouesness, and to identify the need for measuring the instability of planning systems. Using such a measure, performances of different procedures could be easily compared. To compare the metrics on instability, it is observed that none of the metrics reflects all the properties of instability and each of them has some shortcomings: some of them are not normalized, some are biased, and most of them do not represent all kinds of uncertainties such as cancelled setups, new setups released, or order sizes increased or decreased. For these changes, the weights are considered to be the same in all the metrics. Also, due to the difficulty to measure long-term instability, short-term instability was measured in terms of setup and quantity based changes.

Furthermore, we present several alternative strategies which have been suggested in literature to dampen the instability in MRP systems, one of the most frequently encountered approaches is freezing a portion of the schedule. In addition, the impact of freezing parameters on instability in different settings has been investigated especially in studies of Sridharan and Zhao. It is observed that increasing the freezing proportion reduces the schedule instability while increasing total cost.

REFERENCES

Blackburn, J. D., Kropp, D. H., Millen, R. A., Comparisons of strategies to dampen nervousness in MRP systems, *Management Science,* 32, 413-429, 1986.

Heisig, G. *Planning stability in materials requirements system*, Springer-Verlag Berlin Heidelberg, 2002.

Inman, R.R., and Gonsalvez, D.J.A., Causes of Schedule Instability in an Automotive Supply Chain, *Production and Inventory Management,* 37, 2nd Quarter, 26-31, 1997.

Jensen, T., Measuring and improving the planning stability of reorder- point lot-sizing policies, *International Journal of Production Economics* 30-31, 167-168, 1993.

Kadipasaoglu, S. N., and Sridharan, V., Measuring of instability in multi-level MRP systems, *Int. J. Prod. Res.*, Vol. 35, No. 3, 713-737, 1997.

Kimms, A., Stability Measures for Rolling Schedules with Applications to Capacity Expansion Planning, Master Production Scheduling, and Lot Sizing, *Omega, Int. J. Mgmt. Sci*. Vol. 26, No.3, pp 355 – 366, 1998.

Kok, T., and Inderfurth, K., Nervousness in inventory management: Comparison of basic control rules, *European Journal of Operational Research,* 103, 55-82, 1997.

Silver, E. A., Pyke D. F., and Peterson R., *Inventory Management and Production Planning and Scheduling*, 3rd Edition, John Wiley and Sons, 1998.

Sridharan, V., Berry, W. L., Udayabhanu, V., Freezing the Master Production Schedule under rolling planning horizons, *Management Science,* 33 (9), 1137-1149, 1987.

Sridharan, V., W.L. Berry and V. Udayabhanu., Measuring Master Production Schedule Stability under Rolling Planning Horizons, *Decision Sciences* 19,147-166, 1988.

Sridharan, V., Berry, W. L., Freezing the master production schedule under demand uncertainty, *Decision Sciences*, 21 (1), 97-120, 1990.

Sridharan, V., LaForge, R. L., Freezing the master production schedule: Implications for Fill Rate, *Decision Sciences*, 25 (3), 461-469, 1994.

Unahabhokha, C., Schuster, E. W., Allen, S. J., Master Production Schedule Stability under Conditions of Finite Capacity, 2002.

Vollmann, T. E., Berry, W. L., Whybark, D. C., *Manufacturing planning and control systems*, 4th edition, Irwin, Homewood, III, 1997.

Xie, J., Zhao, X., Lee, T. S., Freezing the master production schedule under single resource constraint and demand uncertainty, *International Journal of Production Economics*, 83, 64-84, 2003.

Zhao, X., Lam, K., Lot-sizing rules and freezing the master production schedule in material requirements planning systems, *International Journal of Production Economics*, 53, 281-305, 1997.

Zhao, X., Xie, J., Jiang, Q., Lot-sizing rule and freezing the master production schedule under capacity constraint and deterministic demand, *Production and Operations Management,* 10, no. 1, 45-67, 2001.