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Demand amplification in supply chains of mills close to and far from main markets

Abstract

Six paper machines, three in Scandinavia and three in the middle of Europe, are studied for their end-market and mill demand patterns. The well-known demand amplification effect is proven valid for mills with long supply chains, while the situation is different for mills located close to their end-markets. The paper shows that the existing reaction time for market demand information is not being exploited and that production allocation is not being well matched with real demand. Mills close to demand do have an advantage over those in Scandinavia, but it is also shown that this advantage could be overtaken by shorter production cycles and better integrated supply chain operations that add up to reliable operational performance with no safety margins and buffers. It is concluded that the physical distance between mill and market should only show up in transportation costs, but not in poorly managed material flow with high buffers and poor customer service resulting from biased demand information at the mill.

Tiivistelmä

Tehtaan ja päämarkkinoiden etäisyyden vaikutus jakelulogistiikan kuormitustusheilahteluihin

Artikkelissa tarkastellaan kuutta paperikonetta, joista kolme sijaitsee Skandinaviassa ja kolme keski-Euroopassa. Erityisesti selvitetään kuinka todellinen loppukysyntä välittyy tehtaille jakelukanavan kautta ja kuinka tämän kanavan pituus vaikuttaa kysynnän vääristymiseen tehtailla. Tunnetusti pitkät jakelukanavat ovat aiheuttaneet voimakkaita kysynnän vaihteluita tehtailla, vaikka itse loppukysyntä onkin pysynyt suhteellisen vakaana. Tarkasteltaessa tätä ilmiötä kuudella paperikoneella huomattiin, ettei tilausaikojen mahdollistamaa pelivaraa hyödynnetä parhaalla tavalla tuotantoa ajoitettaessa. Tehtaalle välittyvä kysyntäinformaatio on vääristynyt tiedonkulun viipeiden ja virheellisten ennusteiden johdosta. Lisäksi tuotannon karkeakuormituksen pitkät syklit estävät toiminnan mukauttamisen kysynnän rytmiä vastaavaksi. Keski-Euroopassa sijaitsevilla tehtailla on etulyöntiasema pohjoismaisiin tehtaisiin nähden, mutta lyhyemmillä tuotantosykleillä ja paremmin integroidun jakelulogistiikan avulla tämä etumatka voitaisiin kuroa kiinni. Parhaimmillaan fyysinen etäisyys markkinoista näkyy vain kuljetuskustannuksissa, mutta ei useissa huonosti kiertävissä varastoissa, jotka eivät kuitenkaan takaa korkeatasoista asiakaspalvelua. Poistamalla toiminnasta ylimääräiset varmuusmarginaalit, niin toimitusmäärien kuin ajoituksen suhteen, ja paneutumalla läheisempään yhteistyöhön jakelukanavan eri toimijoiden kanssa pystytään rakentamaan keskellä markkinoita toimivien tehtaiden veroinen palvelukonsepti.

Introduction

The phenomenon called industrial dynamics refers to the seminal research of Forrester /1/ in the 1950s. For industrial management, the leading idea of this research was that the myriad material flows of manufacturing industries are managed on the basis of biased information. Inventories and buffers of multiple operators in the supply chain create delays in information transfer preventing true market information passing on to the source of the material flow. The result is a vicious cycle, with the situation getting worse as time goes by. Once the flow suffocates itself the economic situation in that industry breaks into a recession, because oversupply kills demand at the factory and prices drop until the excess in the supply chains has been resolved. Once supply recovers, demand exceeds it and the good times return. Greatly simplifying the theory of industrial dynamics, Forrester went on to explain that whole economic recessions are caused by this kind of mechanism related to slack and non-materialised sales. The logic is still plausible and the devastating power of demand amplification has been witnessed in most industries.

Scandinavian paper mills serve most of their customers through various operators and forwarding units in their lengthy supply chains. This means that industrial dynamics prevail in these chains, and that Scandinavian mills experience major demand surges, which make production planning as steady as a ride on a roller coaster. The traditional way to tackle this problem has been to reduce the number of players in the supply chain, i.e. the mill seeks to serve the customer either direct or via as few other operators as possible /7/. The persistently prevailing long production cycles have also been shortened in advanced mills to match customer demand more closely, together with more frequent and better adjusted sizes of single deliveries. These improvements are still very much valid and their application is highly encouraged, as the results achieved are extremely positive /4-5/. The point of this article is to benchmark mills that are far from and close to the main markets, and to learn from both types of case.

In the following the research setting and problems are formulated and the mills in the sample are presented. The empirical results on demand amplification and reaction time for true market demand are then evaluated for each mill. By differentiating according to each mill's geographical location the results are presented in two lots. The results obtained are benchmarked and guidelines for best practice are outlined. Finally, conclusions are drawn on the impact of distance between the market and the mill.

Problem setting, methodology and the sample

The underlying research problem in this article is to study the existence and patterns of industrial dynamics in long and short supply chains in the paper industry. Particular attention is given to demand amplification, i.e. to the bias between end-market demand and its reflection at the mill. This is somewhat novel, as earlier research mainly examines the demand amplification in supply chains with several operators and ignores comparisons with shorter ones. Against this background, this paper looks at the following research questions:

- How does the demand amplification differ between long and short supply chains in the paper industry?
- How does the reaction time to market demand vary between mills located close to and far from the markets?
- How can mills with long supply chains achieve an unbiased demand pattern?

These problems are studied for mills located in inland Scandinavia and in the middle of Europe. Altogether six machines and their demand patterns are tracked using quantitative data downloaded from the production and sales management systems of each mill. In each case, the data represented more than 10 months of operational records, i.e. on the level of the deliveries to individual customers right from the machine

to the end-customer. In practice this means that several thousand past deliveries were analysed per paper machine. The validity of the data was checked against the volumes produced and invoiced. The method is based on quantitative controllability analysis /2/, where every analysis and conclusion is based on real data and not on "gut feelings". Although the machines in the sample differ from each other in terms of product mix, volume and strategic positioning in the markets, their customers and supply chains share many features, enabling fruitful benchmarking of the results. Table 1 summarizes the main features of the paper machines.

The sample is heterogeneous in terms of volume and products delivered, but operations related to supply chain control and customer service are exactly the same. Production must adapt to changes in demand, which inflicts demand amplification and eventually problems at the mill. The sample includes both cardboard and fine paper mills, which might be considered incompatible, but in terms of sales and logistics their operations are much the same. At several Scandinavian paper companies the sales offices manage both paper types, and thus employ similar procedures for their ordering and delivery routines. The end-customer is hiding behind not just the sales off ice but also the wholesaler. This structure makes the supply chain highly vulnerable to the demand amplification effect. On the other hand, in central Europe mills normally deliver direct to the end-customer, in addition to employing a wholesaler network. Some mills deliver longer distances using allies and other partners [8], yet most of their volume is delivered direct to the end-customer.

Empirical results

For each machine, end-deliveries and volumes ordered were summed on a weekly basis and plotted during the 10 - 12 month analysis period. In practice cutting the time series from the continuous process causes some problems at the beginning and end of the series, but this has been taken into account in examining and processing the results, i.e. the reliable period for the analysis is usually much shorter than the sample taken from the mill's information systems. Here, end-delivery means the final and last delivery to the end-customer. This may have taken place either from the mill, which is often the case for central European mills, or from the sales office or wholesaler of the Scandinavian paper company concerned. Ordered volumes are calculated from the customer orders produced per week at the mill. This means that the order handling routines at each mill play some role in the visible results, that is if safety margins are used to secure timely deliveries. In addition, the time between the arrival of the order at the mill and the due-date for the delivery to be ready at the mill was calculated to see how much reaction time each mill has on average to meet the market demand.

Fig. 1 sums the situation for the Scandinavian paper machines. There is a certain discrepancy between tons produced and tons delivered tons. This merely indicates that the supply chain hosts stocks that are also used to satisfy demand. This also biases the market information at the mill. The analysis also calculated the average throughput time between the paper machine and the end-customer. One should be cautious when using this measure, as it hides in the huge fluctuation of throughput time distributions between various grades and deliveries. Nevertheless, it provides the reader with an overall view of the supply chain performance. In general, the use of averages to assess production and logistic performance is dangerous, as it tends to obscure the real operational problems of the mill. Fig. 1 also details the average production cycle or the aggregate planning cycle of the mill.

As earlier studies /3-5/ on the Scandinavian paper industry show that the prevailing production management strategy is based on high volumes with long production cycles resulting in very long average supply chain throughput times. Machine #1 represents mills in this category, which are confronting demand amplification problems of a larger scale. Machine #2 is already approaching better performance through shorter cycles and fixed delivery performance, but has some way to go before it reaches the performance of machine #3. The third machine has greatly reduced safety margins in the supply chain

through shorter and more flexible production cycles. Also, the well-balanced product mix at the remotely located mill allows it to adjust better to market fluctuations. Amazingly, the scale of the market fluctuation is practically the same for each mill, although the situations at the mills vary greatly.

The situation for the machines located at the heart of the main markets is shown in Fig. 2. The reader is reminded that all three machines in the central markets have different viewing scales. This means. for example, that for machine #6 the fluctuation takes place within 300 and 1,800 tons per week, while for machine #4 the market demand ranges from 1,500 tons up to 4,000 tons. Despite the scaling, one sees immediately periods completely different from the Scandinavian mills, i.e. the markets are at some points in time fluctuating more than the demand profile at the mill. Also, the ability to react to market fluctuations is much better than at the average Scandinavian paper mill. Clearly the shorter supply chain plays a crucial role here, as it enables the mills to deliver direct to the end-customer. Actually, when the demand lines coincide, the gap between them fits well with the size of the finished goods inventory.

The in-depth analysis indicated that throughput times and their distribution within the mill, i.e. between cutting, sheeting, packaging and dispatch, were almost alike and differences between the two different samples were hard to find. This means that internally the mills are operating in more or less the same way, meaning, for example, that safety margins in to-be-sheeted-reel-inventories are used in a similar manner, and the volume in orders is produced unnecessarily in advance to secure punctuality. The true difference is in the supply chain structure outside the mill, which makes life somewhat easier for centrally located mills. However, machines #2 and #3 are already moving in a better direction. With a history of substantial restructuring, reshaping of the product palette and shortening of production cycles, these machines show that demand amplification can be controlled even with long supply chains. These positive results, together with the experience from mills located close to market, enable us to outline the following measures to ease demand distortion and surge effects in supply chains:

- Fixed and short production cycles to produce a well-matched product palette. This is fundamental, as the mill dictates rhythm for the entire material flow in the supply chain. Also, the ability to deliver smaller lot sizes at shorter intervals improves capital performance through a better turnover of inventories. Production cycles of one week for major grades seem to set some kind of best practice for all kinds of mill. However, the cycle must be fixed in order to build confidence in the whole chain and eventually in the end-customer, who gradually can and will rely on fixed deliveries of smaller and better adjusted lot sizes.

- Accurate performance with no safety margins. In a loosely connected value chain, the operational units aim to optimise their own processes, which does not sum up in optimal overall performance. Safety margins represent one of the main problems for these value chains, as each operation wants to secure its best performance, usually based on volume and other output measures. These safety reservations, e.g. allocating an order to the first cycle instead of the last possible one, or increasing the initial order volume with some extra to secure a good level of service, seem to be harmless actions, but their cumulative effect can be devastating. First of all, they hide the true performance of the system, and generate biased information through unnecessary stock levels and demand estimates. Operations must be evaluated on their true performance, not on anticipations and forecasts; this highlights not just the problems but also the progress being made.

- Direct access to true demand information. Whatever the means - information technology or conventional communication - passing real demand information on to the mill with the minimum of delay is of the outmost importance. Simple procedures, like fixed communication intervals on consumption during the past and present production cycles between wholesalers and sales people before fixing the content of the coming cycle, form a sound basis for improving the quality of the demand information. For the paper machines studied here, almost 80% of the volume to be

produced was known before two weeks of the due date. This is enough to adjust the whole supply chain to operate much more accurately.

- Partnering and better acquaintance with customers. Partnering is something that exists in talks between consultants and managers rather than on the operational and material flow levels. Mills in central Europe are in no better position than Scandinavian mills when it comes to knowing the sales and value adding processes of their customers. Because of competition, partnering and customer service will experience a significant leverage in the paper industry, when its customer-supplier relationships should resemble the ones prevailing in advanced assembly industries**.** Companies exploiting this potential first will outperform the others.

These actions are intertwined and overlapping, yet they converge towards the same goal, namely to improve supply chain performance through better control and reliability. In addition demand amplification has also been studied theoretically /9/ through mathematical models and simulations. In practical terms, the obvious result has been that dynamic behaviour prevails with systems where phenomena are interrelated through multiple feedback loops. When this feedback information from the different players in the supply chain is delayed and biased, the resulting behaviour is stochastic and unpredictable. The only way to reduce the turbulent outcome is to shorten delays, add discipline in operations, and improve the quality of the information in the process. This translates into supply chain management language by saying that safety stocks must be minimized and true demand information has to be passed to the mill, preferably in real time.

Conclusions

Be it a supply chain or a value-adding manufacturing process with several consecutive operations, the effect of demand distortion is present. Practically all problems of production and supply chain management can be reduced to relationships and connections between the operations and how they are orchestrated together to achieve the best overall performance. This paper has shown the industrial dynamics in action in both long and short supply chains. The general result is obvious, the shorter the chain the milder the demand amplification effect. Yet, the novelty in the analysis documented is that mills with long supply chains can tackle the problem and challenge mills with short supply chains in operational terms, if they adapt strict principles to their operations control. Shorter and fixed production cycles based on real market information together with partnering and collaboration with forwarding units and customers will pave the way.

The cases show that the biggest obstacle to progress has been the lack of confidence in the supply chain, i.e. that the mill can and is really able to deliver smaller lot sizes at shorter and fixed intervals. This means again that efforts must be directed towards better communication, esteem building and education in the whole chain, before real progress starts. However, measuring progress and integrating operators under a common assessment system makes things easier, as hard facts make believing easier. In the international paper business the winners are to be picked, as the competition on operational level is starts /6/. Paper mills are in general slow and their operations and supply chains hold significant amounts of idle stock. Those mills that take the initiative have the best prospects of reaping the benefits. As this paper has shown, distance from the markets does not have a crucial effect on the mill’s operational competitiveness.

References

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PM #	***Location / type of supply chain***	***Volume***	***Product mix***	***Production strategy***
1	Inland Scandinavia with long supply chain using all modes of land transport. Sales offices and wholesalers before the end-customers.	Medium sized machine, volume 120,000 tons per annum.	Standard cardboard products.	High service standards within wider than normal production range.
2	Close to coast in Scandinavia with integrated connection to harbour. Sales offices with well established wholesaler network.	Medium sized machine with volume of 140,000 tons.	Bulk paper products, with customized features.	Well-focused standardized products produced in high volumes.
3	Inland Scandinavia with streamlined connection to harbour. Country-specific sales offices, with most of the volume passing through wholesalers.	Medium sized machine, close to 120,000 tons per annum.	Standard office paper, with certain degree of customization.	High volume and good customer service combined with flexibility.
4	Central Europe with short supply chain, but also long-distance customers. Direct deliveries to customer. Small amounts via wholesalers.	High volume machine with over 200,000 tons annually.	High volume of standardized fine paper products.	High volumes with narrow standardized product mix.
5	Central Europe and close to key customers. Direct customer deliveries.	Medium sized machine with volume of ~125,000 tons.	Standardized office paper with some customization.	High volume and customer driven production with narrow non-standardized product mix.
6	Central Europe, short supply chain with deliveries direct to the end-customer. Direct customer deliveries.	Small volume, round 75,000 tons.	Customized dimensions of printing paper for print shops.	To serve end-customers with customized products. Small lot sizes with final goods inventory reserve.

Table 1. The sample of six paper machines (PM) used to analyse demand amplification.

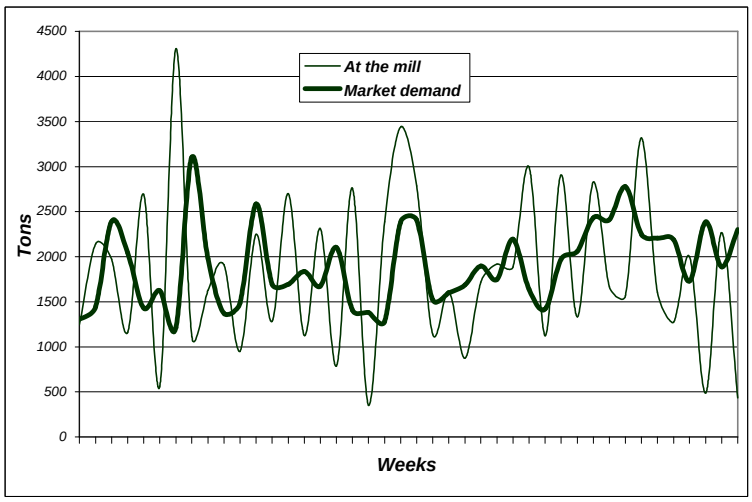
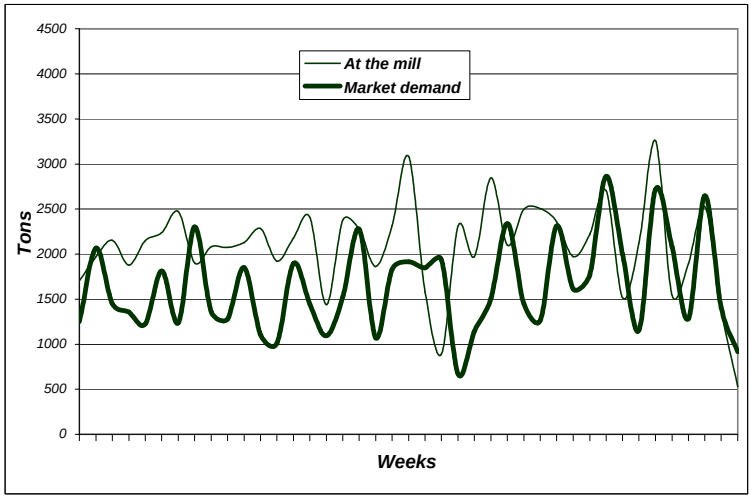
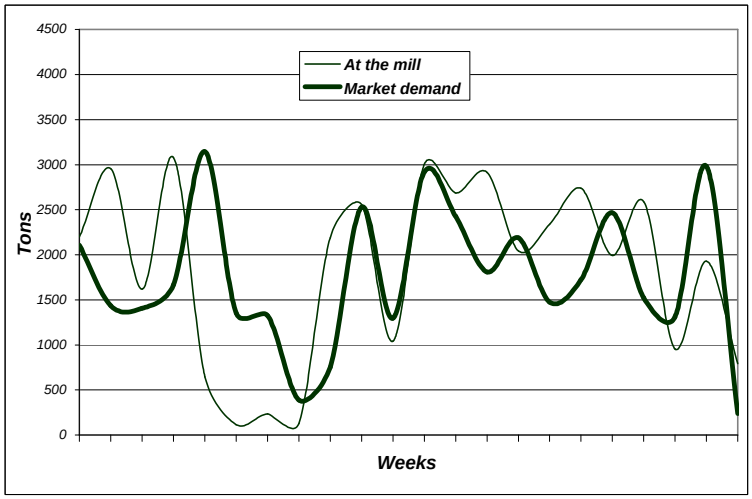
Machine #1 	**Ordered:** 77,000 tons **Delivered:** 82,000 tons **Rough product mix:** 70% reels, 30% sheets **Production cycle:** 4 weeks, main grades run twice in a cycle **Average throughput time:** 75 days for reels, over 100 days for sheets **Reaction time:** reels 40% of volume within 2 weeks due time, sheets only 5% within 2 weeks, average time 3 weeks **Comments:** mill fluctuation significant when compared to market demand, even during steadier periods in the market the ordered demand fluctuates. The mill is experiencing a powerful demand amplification effect, one obvious reason for this being the relatively long production cycle
Machine #2 	**Ordered:** 85,000 tons **Delivered:** 67,000 tons **Rough product mix:** 30% reels, 70% sheets **Production cycle:** 2 weeks **Average throughput time:** 40 days for reels and 65 for sheets **Reaction time:** 30% of reels needed before two weeks, sheets only 20% within a fortnight, average time around three weeks **Comments:** due to coming changes in production cycles the first half of the period experienced over demand production, towards the end of the period mill demand follow in harmony end-demand, still in the middle of the period significant distortion can be detected, in the end the shorter production cycles improve situation significantly
Machine #3 	**Ordered:** 41,000 tons **Delivered:** 38,000 tons **Rough product mix:** 40% reels, 60% sheets **Production cycle:** one week, with low volume grades run when needed **Average throughput time:** 35 days for reels and 50 days for sheets **Reaction time:** 25% of reels and sheets needed before two weeks, on average well over three weeks' time to plan **Comments:** despite the end market fluctuation the mill pattern does not show much fluctuation, smaller volumes with short production cycles enables the mill to adjust well to market fluctuations. Also, the well integrated supply chain reduces the information bias, which shows in the analysis

Fig. 1. Forrester effects for Scandinavian paper machines, i.e. the difference between market demand and biased demand. Average throughput time refers to duration from the mill to the end-customer. Volumes in tons are based on the period studied.

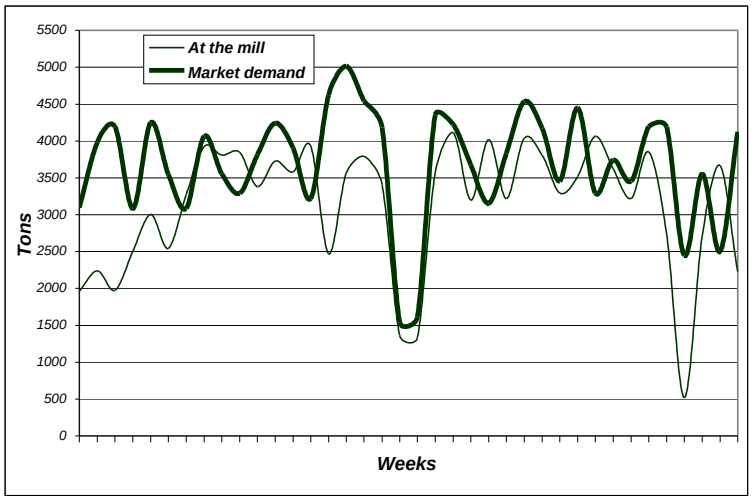
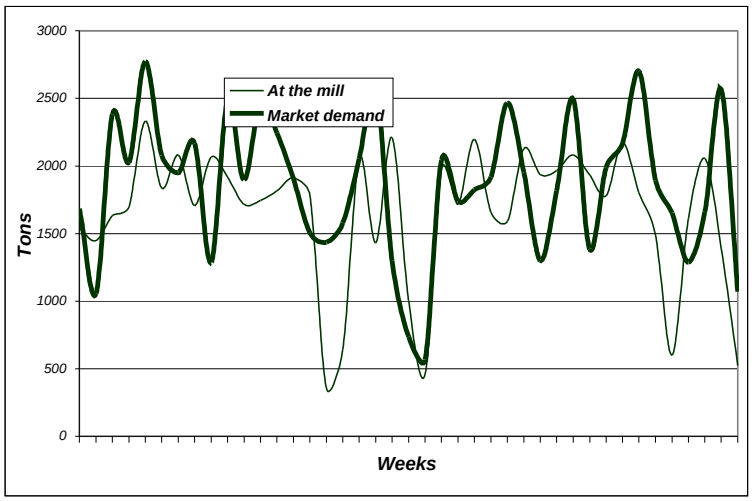
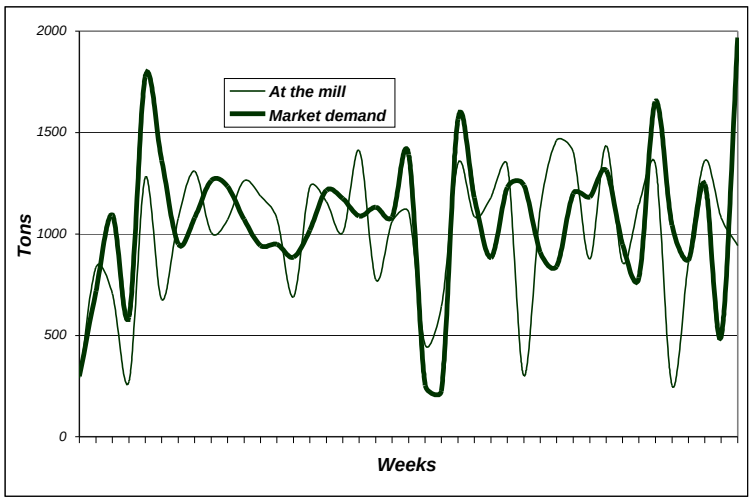
Machine #4 	**Ordered:** 124,000 tons **Delivered:** 149,000 tons **Rough product mix:** 65% sheets, rest reels, only standard office dimensions **Production cycle:** one week for 95% of the volume **Average throughput time:** sheets 35 days, reels 21 days **Reaction time:** 80% of the volume has over two weeks' time to be finished **Comments:** short production cycle with plenty of reaction time enables the mill to adjust extremely well to fluctuations in demand; both demand patterns indicate that deliveries are being made directly from the finished goods inventory to the end-customer
Machine #5 	**Ordered:** 69,000 tons **Delivered:** 78,000 tons **Rough product mix:** 40% sheets, 60% reels, standardized high-volume products with rather broad weight profile **Production cycle:** one week for key grades and two for the rest **Average throughput time:** sheets 40 days, reels 18 days **Reaction time:** almost 90% of the volume is due in two weeks from the time the order is received at the mill **Comments:** periods when demand fluctuates more than the situation at the mill, well phased rhythm within a reasonable volume range, adaptability excellent even for sudden large fluctuations
Machine #6 	**Ordered:** 42,000 tons **Delivered:** 45,000 tons **Rough product mix:** 80% sheets, 20% reels, customized dimensions for printing shops **Production cycle:** week for volume grades and two weeks or more for others, evenly dispersed product palette **Average throughput time:** 35 days for sheets, and three weeks for reels **Reaction time:** 90% of sheets have over two weeks' planning time, less for reels **Comments:** fluctuation takes place over a very narrow range (500-1500 tons), the variation in the length of the production cycle generates slight dispersion in the otherwise well matching demand pattern, reaction to sudden jumps in demand is well managed

Fig. 2. Paper machines located in central Europe and their Forrester effects (note: the scaling is different because of major differences in volumes).