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A benchmark study of 12 fine paper machines on operational efficiency

Abstract

The main results from the operational analyses of 12 fine paper machines are compared and discussed. The key metrics studied for each machine were annual production volume, number of paper grades produced, and average throughput time with its variation in the whole supply chain from paper machine to customer. The variation in throughput time has been calculated in terms of the cost saving potential that would be realised if the whole material flow passed each step in the chain within 7 weeks from its initial production date. To justify this calculation, the assumptions made in relation to inventory carrying costs are discussed. The results indicate that machines turning out numerous paper grades tend to have longer throughput times in their supply chains, although exceptions do occur. Neither annual volume nor paper machine capacity has any clear correlation with throughput time. It is also shown that longer throughput times entail more variation in the supply chain. The fundamental result of the benchmark study indicates that, independent of the paper machine's size or the number of products being produced, a mill can be operationally efficient and outperform others in the market. The mills in the sample were studied during 1995 and 2000.

Tiivistelmä

Operatiivisen tehokkuuden vertailu 12 hienopaperikoneella

Operatiivista tehokkuutta mitattiin ja osin kehitettiin 12:lla hienopaperikoneella vuosien 1995 ja 2000 välisenä aikana. Koneiden keskinäisessä vertailussa tutkittiin koneiden kokonaisvolyymin, eri paperilaatujen määrää ja tuotannon läpimenoaikoja ja niiden hajontoja koko jakelukanavassa aina paperikoneelta loppuasiakkaalle. Läpimenoaikojen hajontaa on mitattu kustannussäästöpotentiaalilla, mikä realisoituisi jos koko paperikoneen tuottama materiaalivirta jokaisessa toimitusketjun osassa kulkisi alle seitsemässä viikossa. Tämän mittarin perustelemiseksi artikkelissa kerrataan varaston ylläpitokustannusten muodostumista ja sitä kuinka varaston kiertonopeus vaikuttaa niiden kokonaisrasitukseen. Koneiden välisen vertailun tuloksena todetaan, että pääsääntöisesti suuri paperilaatujen määrä ja pidemmät läpimenoajat liittyvät toisiinsa. Tämä ei kuitenkaan päde aina, vaan otoksen joukosta löytyy operatiivisesti hyvinkin tehokkaita koneita laajalla tuotevalikoimalla. Paperikoneen vuotuisella tuotantovolyymilla ei näytä olevan minkäänlaista korrelaatiota läpimenoaikojen kanssa. Aineiston pohjalta voidaan myös todeta, että pitkät läpimenoajat ja niiden suuri hajonta kulkevat käsi kädessä. Pohjimmiltaan koneen ja tuotepaletin suuruudella ei ole kummallakaan ratkaisevaa merkitystä, aina voidaan toimia operatiivisessa mielessä tehokkaasti. Pääsääntöisesti yhteistä tehokkaille koneille on lyhyet ja kiinteät tuotantosyklit, fokusoitu tuotepaletti ja saumaton yhteistoiminta kanavan eri osapuolien välillä, millä taataan luotettava ja oikea-aikainen tieto todellisesta kysynnästä.

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Introduction

During the past five years 12 fine paper machines have been studied in depth by calculating their operational performance in terms of production cycles, value-added production, and capital bound to inventories in the whole supply chain. Some of the machines were earmarked for major development projects and were analysed later to see how process changes affected productivity and operational speed. In this article these results have been made commensurable and are dealt with as one sample in order to work out the best practices in fine papermaking.

Earlier studies /4,5/ indicate that operational performance in the paper industry is not good, and that companies are still competing in terms of volume, acquisitions and raw material prices. Compared with other industries, the pulp and paper industry was found to be generally operationally slow and low in value creation. It has also been reported /6/ that a paper mill may significantly improve its operational performance by shortening production cycles and focusing its product palette together with better integration with players in the supply chain. Changes in a mill’s operational principles have generated far-reaching improvements in the whole supply chain, with lower inventories and greatly improved delivery performance. It is clearly foreseen that the future winners will be those mills that make operational performance their first priority.

Comparing the operational performance of different fine paper machines requires general metrics and an insight into what is taking place at each mill. This was achieved by collecting operational information from mill management and enterprise resource planning systems that reveal each and every delivery in the mills’ material flows during a period of at least one year. This approach is based on a quantitative controllability engineering method /3/, with the emphasis on analysing real data and a synthesis based on the data. The analysis was the same in each case, namely from paper machine to delivery to the final customer. Although case-specific situational variation has been applied when necessary, in general the analyses applied have been similar enough to provide a basis for using benchmarking as a research method.

Before proceeding on to the results, we discuss briefly the benchmarking methodology and the metrics used to compare the paper machines. Graphs have been used to illustrate the situation among the mills. Differences between well and poorly operating paper machines are studied in detail, especially against the changes in managerial principles applied on subsequent paper machines. Finally, conclusions are drawn with an outline of the best practices for managing operations in fine paper manufacture.

Benchmarking and metrics

Benchmarking is a performance measurement tool used in conjunction with improvement initiatives. It compares the operating performance of companies and identifies the “best practices”. It is recommended that benchmarking be carried out across companies and units that are operating in different fields. The search for best practices should not be limited to any particular branch of industry, nor is benchmarking against market leaders always the right approach. For a company that is lagging way behind a rival, mimicking the leader’s operational practices may often worsen the situation, because of the leader’s headway in the learning curve which cannot be matched by just copying managerial and operational processes. In the end benchmarking aims to create value by:

- Focusing on key performance gaps
- Identifying ideas from other companies
- Creating a consensus to move an organisation forward
- Making better decisions from a larger base of facts.

Benchmarking can be applied in many ways, and when combined with advanced mathematical methods and dynamic presentations it can produce quite staggering results (for an interesting case on the paper industry see /2/). Our 12 fine paper machines make up a highly homogeneous sample, which seems to be contrary to the very essence of benchmarking. In defence, it should be pointed out that these machines are located in different places in Europe, they share some of the same clientele, and still use in many ways very different operational principles. Further, among the sample there are mills that have introduced significant change programmes towards leaner operations, while others seem to have simply drifted into their current status. The sample thus contains major differences and can be used to pinpoint major operational advantages at mills that seem to outperform conventionally operated mills. However, in the strictest sense of benchmarking, we cannot call these practices "best", though they can perhaps be described as good practices that seem to make a clear difference. The metrics used to compare the machines are:

- annual production volume, based on realised production, not budgeted, nor on the nominal capacity of the paper machine;
- the number of paper grades produced, i.e. the number of products with different grammages and finishing;
- average throughput time measured from individual deliveries that have passed the whole supply chain from paper machine to end customer;
- variation in throughput time, which has been calculated in terms of cost saving potential that would be realised if the whole material flow passed each step in the supply chain the chain within 7 weeks, summed over the whole chain from initial production date to final delivery date.

While the first three measures are probably clear, the last requires some clarification. Cost saving potential refers to the cutting of variations in throughput times. It is normal that mills consider that the average throughput time between packaging and dispatching is, say one week, yet they average out the variation in the overall throughput time. This means that normally 7% to 10% of the volume spends much longer time, like more than 7 weeks, in this step. Our empirical studies have shown that by cutting this 'tail' in throughput time distribution produces cost savings of some 3 – 5% of the mill's turnover. To make the measure commensurable across the sample, we have calculated the cost saving potential for each mill through the value of material in all steps of the supply chain that have stayed there longer than seven weeks. By applying 30% inventory carrying cost to this "excess inventory", the overall cost for the throughput time variation can be calculated. In our experience, this type of calculation raises several questions: Why seven weeks, and where does the massive 30% inventory carrying cost come from?

The easiest to answer is the seven-week barrier for the variation. Even in the most fluent material chains with little or practically no variation, the average throughput times are around 2 to 3.5 weeks in European fine paper operations. It is natural that some part of the volume will not make it within the main bulk of the flow. Yet, materials that do not flow in speeds corresponding two times the length of the main bulk of the flow are clearly missing the goals of efficient operations management, hence the limit of seven weeks. In addition, we have not yet found any business-based reason for keeping such inventories.

The question concerning inventory carrying cost percentage is trickier. According to the American Production and Inventory Control Society (APICS), the total supply chain management costs for the best companies are 4 – 5% of company turnover, yet for average companies the usual figure is round 10%. These costs concern the whole material flow, not just that part of the flow staying longer than seven weeks in the various steps of the supply pipeline. Both APICS and the U.S. Department of Commerce refer to levels of 30% as a decent percentage for assessing inventory carrying costs /1/. A typical breakdown would be:

– Capital (short-term interest rate)	8%
– Space (rent/m^2 * area)	2%
– Labour costs (Σ_i (person$_i$ * salary$_i$))	10%
– Fixed capital costs	2%
– Insurance	2%
– Obsolete products, waste, etc.	6%

These add up to 30%, a figure that is seldom used in the paper industry. The pulp and paper industry normally uses figures of between 8% (cost of capital) and 15%. There is a profound mindset behind these numbers. A manager looking at the world from the 10% perspective is much more prone to make, buy and store goods in inventory than a manager with a 30% viewpoint. Some incentives like volume discounts and quota-based production bonuses often support this behaviour. Figure 1 illustrates this myopic situation. With a monthly need for 100 units and modest discounts for buying in lots of 1, 100, 500 and 1000, the different inventory carrying cost percentages prompt the purchaser or producer to act very differently. The one with the 10% perspective and rewarding system is much likely to go for large lot sizes. It is essential to understand how this kind of seemingly harmless coefficient can affect the decision maker's behaviour. In the calculations presented here, the 30% perspective is only applied for the material that has spent more than seven weeks in any single step of the supply chain.

To further consider the point of inventory carrying cost percentage, one can argue that the whole number is useless and only indicative. Fig. 2 shows that if inventories are well managed and inventory turnover numbers are high enough, the whole discussion is unnecessary. The faster the stocks turn the less capital bound to them, and the smaller the role of inventory carrying cost. Well, this is not the case in most of the mills in the sample. Most of them are fighting against the variation in their material flows, but some are mastering the situation much better than the others.

Results

As a sample of 12 mills is not enough for any scientifically valid statistical conclusions, the results are shown in the form of four charts (Figs. 3-6). Each chart is then examined separately. The aim is to study the apparent message of the charts and to combine this with the experience gained from each paper machine during the analysis and development work. To maintain anonymity, the individual paper machines are referred to by means of the calculated indicators. A well-informed insider from a mill in the sample might be able to locate his/her paper mill on the charts. In fact, they are advised to try this in order to better understand the benchmarking results.

The relationship between annual production volume and throughput time in the whole supply chain from paper machine to end customer is shown in Fig. 3. The best performing paper machines have reached the average throughput time of 30 days. In general, a time of less than 40 days can be reached in any supply chain, irrespective of the mill's capacity. For some reason, machines within an annual capacity of around 100,000 – 120,000 tonnes hold the poorest performance. Average throughput time as such is a general indicator and obscures the true performance, yet when calculated over a year it sets a reference for overall operational efficiency. Significant reductions in throughput times are possible, as we all know either from experience or from some regularly cited business cases. In the sample, one mill managed to reduce throughput time over the whole supply chain from an average of 8 weeks down to 3.5 weeks during a period of one year, without any investment in information technology nor machine capacity, just the operational procedures of the mill were changed.

In Fig. 4 paper machine volume is plotted against cost-saving potential. Looking at this figure in conjunction with the previous one clearly shows the general trend that longer throughput times imply larger variation. Perhaps the correct way to put it is to say that an uncontrolled supply chain with lot of variation results in long throughput times. This is not really a chicken-and-egg problem, as it is clear that variation, distortion and poor information cause long throughput times in the whole chain. Having excluded the poor performers from Fig. 4, one is tempted to conclude that larger volumes imply larger variation. This seems to hold true, as larger volumes tolerate better variation, if only average throughput time is considered. With all machines, most of the volume flows smoothly, but with larger machines the bulk of the flow, which runs smoothly overshadows the variation and the slow moving part of the flow.

The number of paper grades made by each paper machine is a measure of the size of the product palette. The relationship between the number of paper grades per paper machine and throughput time is plotted in Fig. 5. Again one is tempted to conclude that shorter throughput time correlates with smaller product palette. Most of the paper machines produce 5 to 15 grades, with throughput times ranging from 27 to over 80 days. Paper machines producing over 25 grades operate on average at over 50 days. Adjusting the product palette is one of the fundamental issues when the throughput time in the supply chain is being reduced. Very often mills carry old products in their production programmes, some of which could easily be replaced with other products from the quality point of view. Some of the sample mills reduced their throughput times significantly by rationalising their product portfolio. Product allocation across many machines and mills within a larger corporation can generate substantial savings.

Variation and its cost-saving potential is plotted against the number of paper grades produced in Fig. 6. This shows roughly the same as the previous figure, yet there are some nice exceptions. The machine with over 40 grades managed its vast product palette very efficiently, and the cost-saving potential is the same as that of machines producing around 10 to 15 grades. This is possible through a strict production discipline and close partnering with the players downstream in the supply chain. The variation among the machines producing 5 to 15 grades is huge, implying that some mills are operating at significantly higher efficiency.

Knowing these supply chains and their operational principles inside out makes it possible to identify some general good practices that make the difference in operational performance between the poorly and well performing mills. It should be remembered that even though to many readers these practices may seem obvious, it is precisely these differences that separate the high-performance mills from the rest. The good operational practices derived from the sample are:

- Fixed production cycles. Paper machines that have production cycles with fixed length, product palette and sequence for each grade do better than those with loose and alternating cycles, product policies and production allocation. In the case of the high-performance machines, up to 90% of the volume produced in the cycle is fixed and the market variation is taken account when individual volumes are determined for each grammage. Mills where the fixed production cycle has been squeezed down to one week, even to five days, clearly outperformed the others. These machines have by far the fastest pipeline from paper machine to market.
- Reliable demand information flows. Fixed production cycles go hand in hand with access to reliable demand information. The exact volumes to be produced in the cycle should be based on real demand. In good cases the demand information is collected periodically, say weekly, from the wholesalers and sales offices to form the production volumes for the next week's production cycle. The use of forecasting methods with poor accuracy is still very common in the paper industry. Simple communication practices with the ten most important partners downstream in the supply chain already make a great difference in the quality of demand information.
- Partnering on the level of material flows. The access to reliable demand information entails partnering on the level of material flows. It is amazing to see how much effort is put into discussing wrapping, new products and market trends with the key supply chain partners, while at the same time issues related to operational performance, inventories, and real demand information are completely ignored. A focus on the material flow throughout the chain is characteristic of the good performers in the sample. This focus is manifested through the metrics used to assess partners, the quality of the market demand information, and shorter production cycles. Knowing exactly what is taking place in the material flow at each step of the logistic chain is fundamental for improving operational performance.
- Focused product palette. Most of the paper machines studied carry in their production programme old and practically obsolete products that could easily be replaced with other existing products. Better communication with customers to keep them aware of the true properties of different paper grades makes it possible to revise the product palette and to narrow it to correspond better with real demand. In some extreme cases delivering over-quality to a customer has resulted in best overall operational performance and financial result.
- Time-based performance metrics. All paper machines measure their output, waste, working hours, employee absences, energy consumption and yield, together with a huge number of other process-related indicators. In none of the cases have we seen

metrics based on throughput times over the whole process from paper machine to final delivery, or any sales-based figures that are shown to the people on the mill floor on a weekly or daily basis. It is actually quite staggering how few people really know the mill's sales figures. Only a fraction of the inventories or buffers along the supply chain are monitored, and when they are controlled it is mainly tonnage that is measured, sometimes inventory cycles but never customer or grade-specific throughput times or their variation. In high-performance companies, time-based metrics have been introduced to complement traditional metrics. They measure delivery punctuality in various operations of the chain, inventory turns, and the variation in throughput times in all steps of the chain.

These good practices are all interrelated and support each other in the drive towards better overall operational performance. There is a lot still to do, even at the mills doing well in the current sample. There are no quick fixes and the only route towards better performance starts from a thorough understanding of the current situation. Only a few of the sample mills knew their true time-based performance throughout the supply chain. However, there are paper mills that after several analyses and development projects have gained the necessary momentum and are determined to achieve an almost monopolistic level of performance that will allow them to out-perform most of the other mills.

Conclusions

Operational performance issues are very seldom on the management agenda of a manufacturing company. It is amazing how many company headquarters in the paper industry see operational efficiency as the sole responsibility of the production units. Operational speed and efficiency are seen as daily activities that do not directly concern the strategic responsibilities of the top management team. In all sample mills there was no clear policy on operations from the top management in terms of which direction to take the mills and how these activities are assessed. In branches of industry where operational competitiveness is decisive for success, the key metrics of overall performance cover the operations of the whole supply chain from the mill to the final customer. As already mentioned, some of the sample mills had set strict operational goals for themselves and the results are already clearly visible: the throughput times are shorter and variation in the supply chain has been considerably reduced. Mills not responding to the challenges set by operational speed and efficiency may be facing a tough future.

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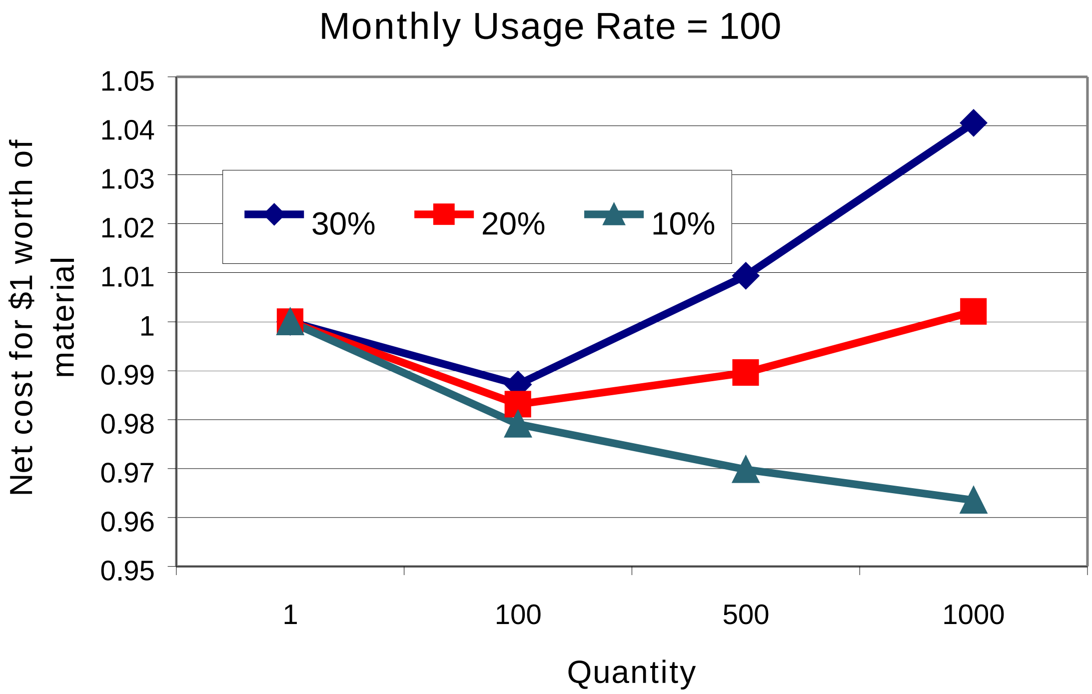

Fig. 1. The higher the inventory carrying cost percentage, the more attractive it becomes to buy in larger quantities because of the associated discounts.

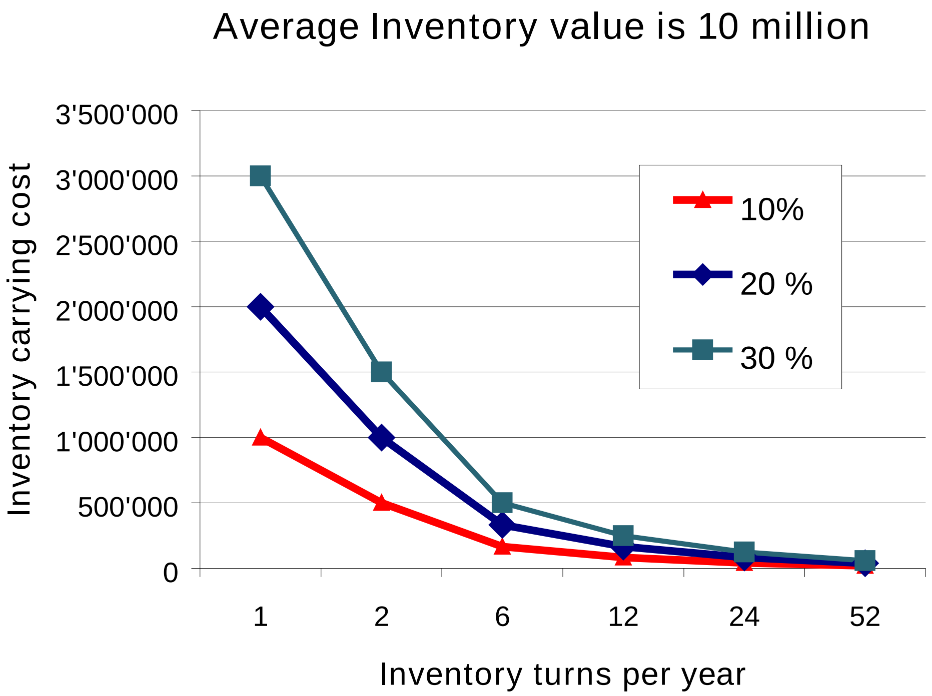

Fig. 2. Inventory carrying cost loses its significance if inventories and operations are managed efficiently.

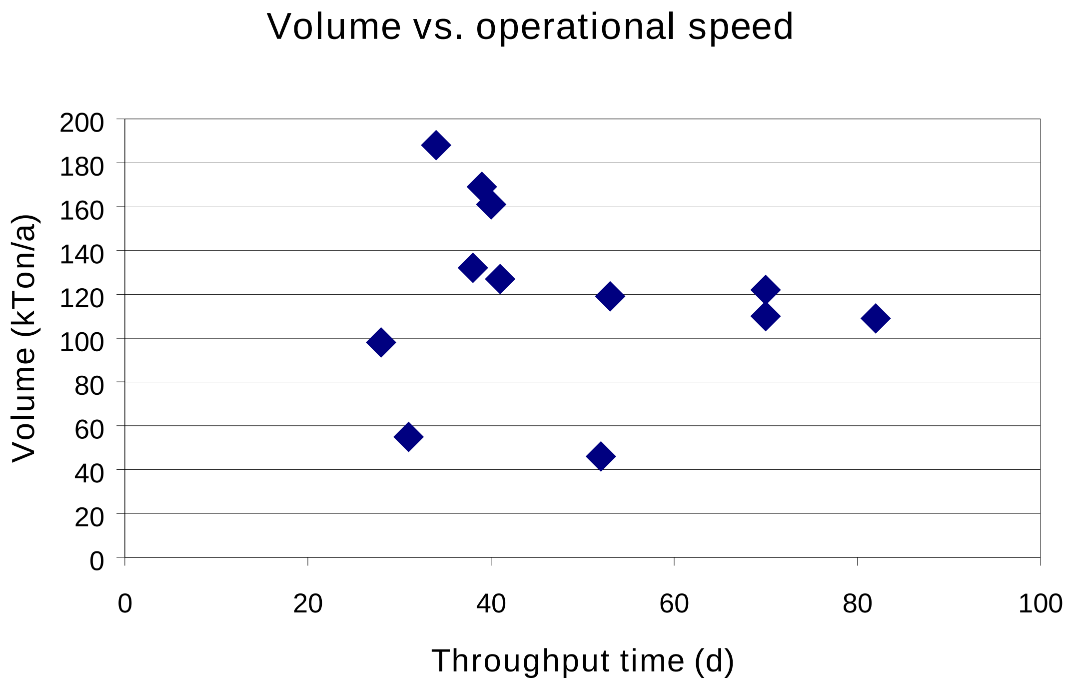

Fig. 3. Relationship between annual volume and average production lead times in the whole supply chain for the machine.

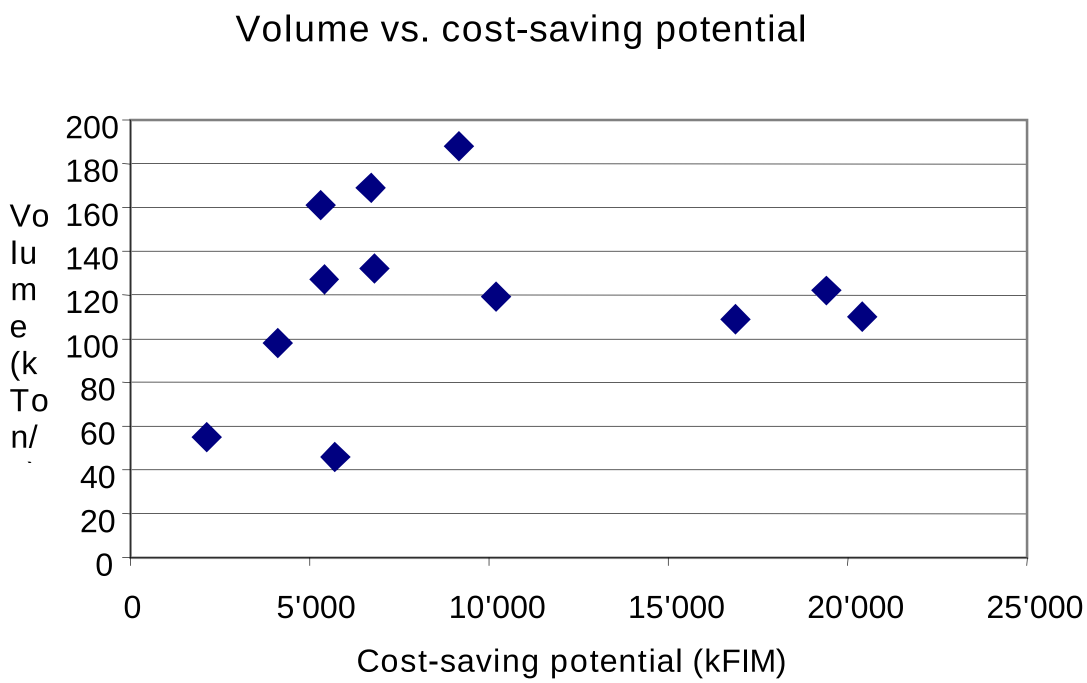

Fig. 4. Relationship between annual volume and cost-saving potential associated with the reduction of variation in production lead times in the whole supply chain.

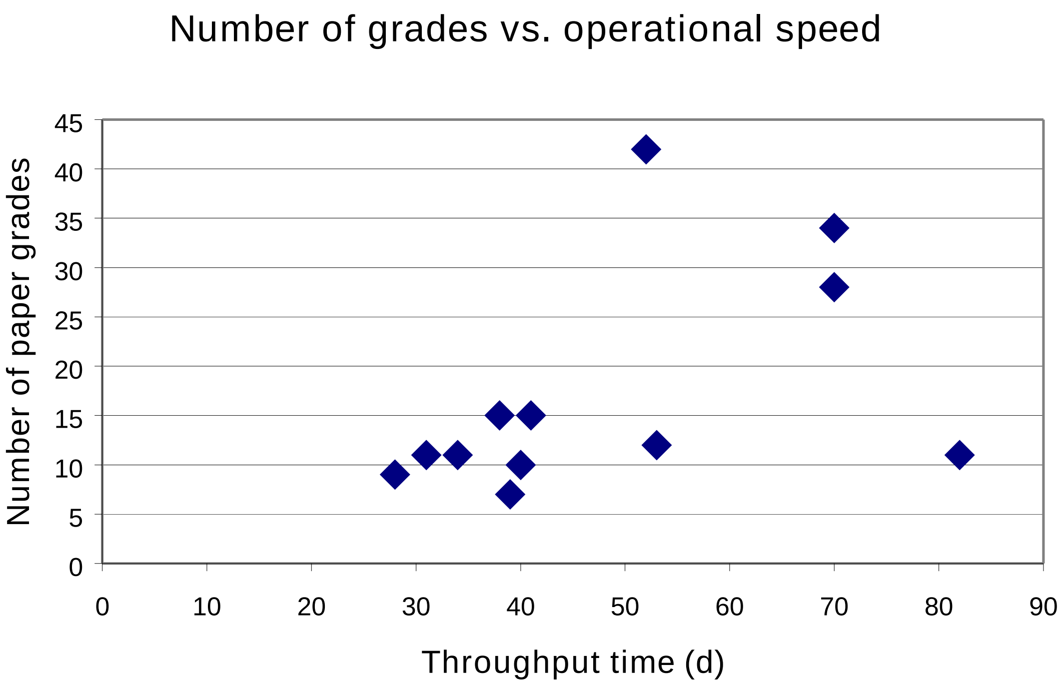

Fig. 5. Number of paper grades produced by a paper machine against the average production lead times in the whole supply chain for the machine.

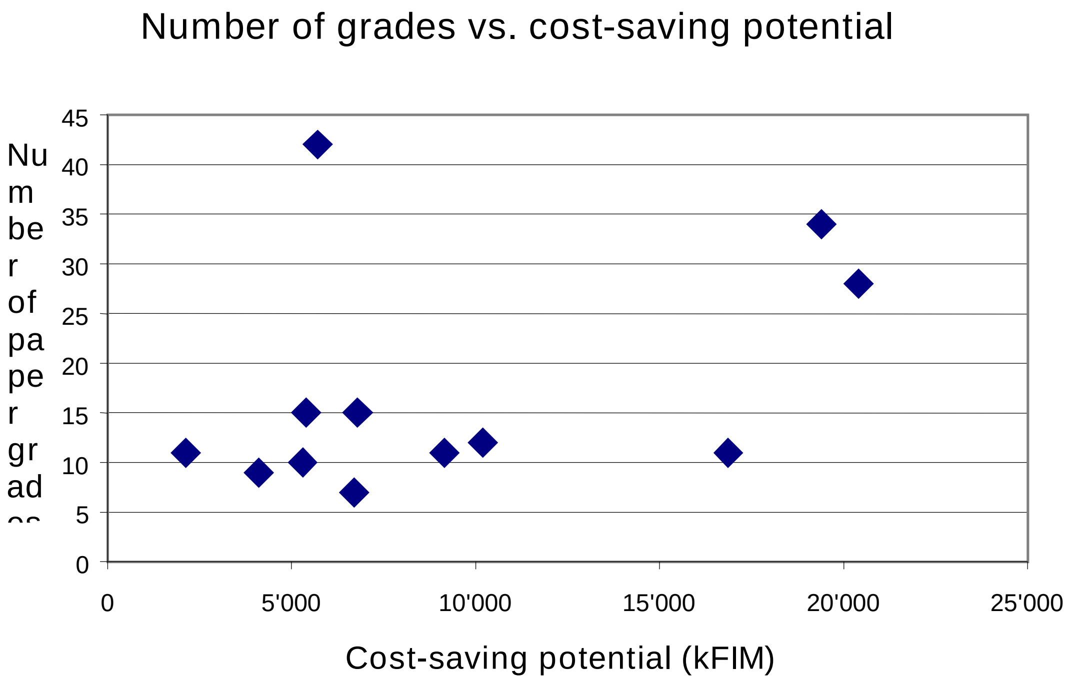

Fig. 6. Relationship between the number of grades produced by a paper machine and the cost-saving potential associated with the reduced variation in production lead times in the whole supply chain.