STATISTICS IN TRANSITION new series, December 2020
Vol. 21, No. 5, pp. 193–206, DOI 10.21307/stattrans-2020-062
Received – 08.09.2020; accepted – 07.11.2020

Flow management system for maximising business revenue and profitability

Piotr Zawada[1], **Włodzimierz Okrasa**[2], **Jack Warchalowski**[3]

ABSTRACT

Most for-profit organisations must constantly improve their business strategies and approaches to remain competitive. Many of them choose to embark on Lean or Six Sigma journeys with the intention of maximising productivity and increasing sales. Despite a significant progress in the development of the Big 3 Improvement Methodologies (Lean, Six Sigma, Theory of Constraints – TOC), many manufacturers are still involved in ineffective operations, resulting in longer-than-desired lead times, late deliveries, high inventories and considerable operational costs. All of these business errors seriously challenge the company's competitiveness. The aim of the paper is to demonstrate the importance of effective analysis of maintaining the appropriate level of inventory in gaining a competitive advantage of the company using the company's key resources in the competitive struggle on the market while conducting continuous reporting of reasons for not achieving the assumed business goals, and using the principles of the economy of bandwidth in order to maximize the profitability.

Key words: inventory, improvement of profitability, economy, management.

1. Introduction

In order to stay competitive and to maximize productivity while increasing sales, many organizations need to continuously improve using innovative approaches, such as Lean or Six Sigma journeys (Mason et al., 2015; de Freitas J., 2017). Sometimes their efforts do not bring the expected results and consume a lot of time and money (Babiceanu and Seker, 2016). Moreover, according to a recent survey, 74% of companies claim to be adopting Lean Thinking Methodology but only 24% claim any kind of positive results. Proponents of this approach believe that one of the most effective way to improve manufacturing business revenue and profitability is to

[1] Cardinal Stefan Wyszynski University in Warsaw, Poland. E-mail: piotrek.za@poczta.fm.
ORCID: https://orcid.org/0000-0003-2817-9578.
[2] Cardinal Stefan Wyszynski University in Warsaw and Statistics Poland, Poland.
E-mail: W.Okrasa@stat.gov.pl. ORCID: https://orcid.org/0000-0001-6443-480X.
[3] CMS Montera Canada, Canada. E-mail: jack.warchalowski@cmsmontera.com.

implement a Flow Management System (FMS) approach. This approach utilizes all 3 improvement methodologies focused by TOC.

The FMS consists of four key components:

1) define inventory position and levels and create a pull-based replenishment signal,
2) identify production streams in the plant, schedule only key resources and reinforce schedule attainment as the primary measure,
3) drive plant-wide continuous improvement process based on the main reasons the schedule is not achieved,
4) base key market and product profitability decisions on the Throughput Economics approach.

Each of the constitutive elements of this approach is discussed in the following sections, together with an indication of its suitability to the problem stated in the title. That is, how it might work for maximizing business revenue and profitability. The structure of the article is as follows. The next section characterizes the first component, devoted to the issue of assuring a balance between sales goals, production plans and the storage time of components taking into account the customer needs. The specification of main positive consequences of the FSM implementation in this context concludes this section. The third section discusses strategic aspects of the production streams and key resources within the schedule attainment reinforcement as the primary measure, along with the issue of adequacy and compatibility of the activities undertaken in the area of production and the required competences of human capital. Drum-Buffer-Rope (DBR) approach – a production planning and execution methodology – which is an integral part of FMS, makes it possible to implement a Continuous Improvement process in the plant. The next section continues the above issues based on a supposition that the main reasons the objectives of DDR have not been achieved can be identified – a Continuous Improvement process that uses Pareto Diagrams comprises reasons hindering the flow through the plant. In the fifth section, the **co**st-per-unit – the most popular analysis process and paradigm of traditional business decision making - which allows managers to use the concept of gross margin to evaluate business opportunities is put under critical review due to its potential distortions and shortcomings. Therefore, the use of a Throughput Economics (TE) based approach, as a part of the FMS approach, taking into account relative product and market profitability, is being recommended along with empirical evidence for its support. The last section summarizes positive effects of using the four-component FMS approach, with focus on the improvement in operational and financial performance of the organizations implementing it.

Define inventory positions and levels and create a pull-based replenishment signal

Stable production systems must, in their assumptions, answer the questions of how to build a balance between sales goals, production plans and the storage time of components necessary for implementation, in many cases very unstable customer orders. This purpose is served by the described system of a competitive advantage use, based on the identification of customer needs and matching production processes with the highest degree of security in the implementation of serial production. FMS focuses first on defining all inventory requirements, utilizing a TOC-based Demand Driven Replenishment (DDR) sizing algorithm, to set up targets for key Finished Goods, Raw Materials and Sub-Assembly items. These inventory buffers break supply chain dependence between unreliable supplier deliveries, variable customer demand and the plant, providing significant stability for the manufacturing operation. Once inventory buffers are in place, a pull-based replenishment signal, in combination with other customer demand, creates the basis for generating the plant load. More stable plant load creates larger production butch for key resources, minimizes their set up requirements, increases overall plant throughput and often reduces manpower. In addition, improved ability to more often make to stock vs. to variable customer demand increase finished goods availability, improves customer service levels and leads to increase in sales. Overall, DDR results in a significant positive impact on business profitability by often reducing operational expenses and driving sales increase at the same time. In addition, DDR, most of the time, results in lower overall inventory levels and / or increased inventory turns. For many years, make-to-order (MTO) has been the preferred approach for manufacturers to use to determine when and in what quantity to make their products. In addition, to help manufacturers buy their required raw materials, they relied on Materials Requirement Planning (MRP) systems.

While the appeal of MTO seems obvious, only make the required quantity of a product once the customer has ordered, the negative side effects are numerous. First, in many manufacturing environments, the customers' order is often their best guess of what they need (their own forecast). Too often customers change either the quantity or the due date of the order. These order changes often force manufacturers to expedite and / or create excess finished goods inventory. Most MTO manufacturers store higher than desired levels of MTO inventory. Second, following an MTO approach often results in periods of high demand (in excess of capacity) and low demand, making it challenging to properly utilize the plant workforce. Both of these issues lead to increased costs through excessive overtime, expediting and even quality mistakes. Finally, following an MTO strategy extends lead time as the product needs to be manufactured after the order is received. This lead time is extended even more when the manufacturer has a backlog of orders. And of course, longer lead times lead to more order changes – a self-reinforcing negative loop.

The appeal of MRP system support is also easy to understand. Explode the customer orders through the Bill of Materials (BOM) and buy only the amount needed to make the customer orders. The allure of minimal inventory and high raw material availability makes the idea of MRP very compelling. However, reality is often very different. Many manufacturers buy items with lead times greater than the lead time they must offer their customers. This issue forces manufactures to feed their MRP systems with forecasted orders. Since it is impossible to accurately forecast at the individual SKU level, the demand changes inflicted on the plant, as the actual orders vary from the forecasted orders, leads to material shortages, expediting, "stealing" and overstock.

MRP is not only trying to help buyers bring in the precise quantity of material, it is also trying to do that at just the right time – not too early or too late. As a result, MRP limits a manufacturer's flexibility. If the customer order changes or a supplier is late with delivering raw materials, manufacturers are often unable to pivot and build something else – as the materials needed to change the schedule are also not available yet. Quality problems in the plant only magnify these issues. While it is true that MRP systems often provide functionality for safety stock and/or min/max inventory level management, these levels are rarely maintained frequently enough to reflect the current often highly variable environment – leading to too much safety stock of some items and not enough of others.

The primary reason that using MTO and MRP leads to all sorts of problems is that manufacturing environments are characterized by high amounts of variability. Variability in the sales orders (dates and quantities), supplier performance (dates, quantities and quality), bill of material and inventory accuracy, and production performance (dates, quantities and quality). MTO and MRP assume low levels of variability and increase a manufacturer's dependence on good, stable performance. As most manufacturers' environments are far from being stable, MTO and MRP too often fail.

FMS, utilizing a DDR approach, minimizes system dependence by positioning inventory in key supply chain points (i.e. Raw Materials, Finished Goods, customer locations, etc.), provides better protection from on-going disturbances, monitors sources of system variability and allows the entire system function at a higher performance level.

2. Identify production streams in the plant, schedule only key resources and reinforce schedule attainment as the primary measure

At the beginning of this part of the study, it is worth considering how necessary it is to ask the following question: "Is it worth to use the strategy to limit your resources to the level which is the most difficult or the most expensive to obtain?". Perhaps, the most important thing is to answer the question "Are the activities undertaken in the area of production accompanied by the required competences to our human capital?"

In the further part of the study, these analyses will be accompanied by the presentation of a solution that minimizes the effects of incorrect production planning. Every plant can be divided into production flow streams. Drum-Buffer-Rope (DBR), a TOC production planning and execution methodology, is used to schedule each production flow stream within the plant and ensures timely production execution. Then, while measuring schedule attainment of each critical resource in a production stream, the reasons and plant locations that most often hinder the flow are tracked and recorded.

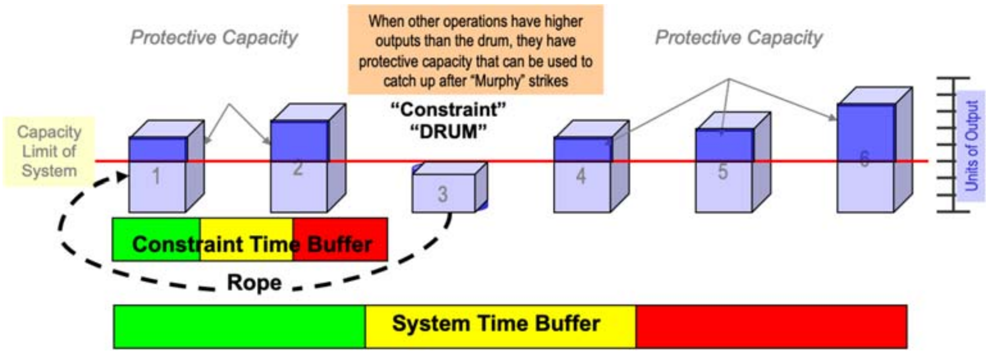

Figure 1. Drum-Buffer-Rope System

Source: Own work.

The Drum is usually the Constraint – for every flow stream in the plant

The drum/constraint is usually the machine restraining your overall throughput. Most of the operations have one constraint (machine or department) for every flow stream in the plant, but sometimes in some plants the drum can follow the product mix changes. In more of a continuous flow operation the constraint is usually located in one place and does not move often with a product mix.

By definition, a constraint can be any resource with customer demand larger than its effective capacity. For every hour lost on this constraint we lose an hour for the entire operation. By the same token, gaining an hour of output at the constraint, increases output for the entire plant. It is also important to realize that every time we elevate the output of the constraint above the capacity level of another resource the constraint/drum will be moved to another plant location. Usually, this is not a preferable direction since it creates an immediate need to redesign the entire production planning and scheduling process as well as manpower management in the plant.

The constraint is called a Drum because it creates the pace for a given flow stream. The speed of the flow stream or its production rate is equal to the throughput of its drum resource. The book "The Goal" by Eli Goldratt was the first one describing this concept. The production schedule is normally set for the drum resource and made visible to the rest of the flow stream. Schedule attainment is closely monitored and evaluated on the shift by shift basis.

From the continuous improvement perspective, improvements of non-bottlenecks have no effect on the overall plant output. Attempts to utilize non-bottlenecks to a 100% capacity (and often above 80%) drive WIP (Work in Process) up, reduce overall system throughput, make the entire system unstable and cause constraint to move from place to place – a wondering bottleneck phenomenon.

The wondering bottleneck phenomenon can be observed most often in the plants with balanced capacity. Balanced capacity means that available effective capacity at every production resource in a flow stream is closely matched to a market demand and each other. The DBR diagram shown in Figure 1 above would show balanced capacity if all work centres from 1 to 6 had the capacity of 3 units. In some plants, with highly variable product mix, balanced production line decreases potential throughput and increases costs – contrary to its original intent.

One of the most strategic question, for any manufacturing operation, that needs to be answered is – where should we strategically position our constraint resource? Sometimes, before resolving this dilemma, it helps to define where we do not want the drum/constraint to be positioned. By definition, non-bottlenecks must have excess capacity. Normally, we will need at least 20% excess capacity at non-constraints to keep the system stable. This is called a PROTECTIVE capacity. Anything above is Excess, and often should be eliminated (good use of Lean Manufacturing techniques to deal with "Muda").

Market availability of resources to acquire, their price, strategic fit are some of the factors that may help you answer the question where and where not to locate your constraint or non-constraint. You certainly do not want your protective capacity to be difficult to find or expensive to buy. Therefore, most probably you want the drum resource to be the more expensive one to get or the hardest to find. You quickly realize that it is the resource that represents your core competence or the reason why you built your business.

Unlike a commonplace definition of inventory buffer, the DBR system Buffer is articulated in the units of time. DBR system buffer is the amount of work expressed in time (hours, days, etc.) before the constraint work centre. The rope mechanism controls the amount of work released to the flow stream by choking its introduction according to the buffer size. By collecting a buffer of work to in front of the constraint machine, we can guarantee the constraint does not starve and never stops. In any given flow stream, the drum is the only machine where maximized (100%) utilization is desirable and beneficial to the system performance.

Buffer's main objective is to mitigate variability of the system. In a traditional Drum Buffer Rope system there are 2 buffers – one protecting the constraint and one for the entire system (flow stream). The role of constraint buffer (before the constraint) is to protect the constraint itself while the system buffer protects the shipping/due date.

All buffers (time and inventory) are divided into three main zones. Colours red, yellow and green designate main buffer sections. In the FMS system two more colours indicate a stock out (black) and too much inventory (blue) - above and beyond its target size indicated by top of the green zone.

Mentioned earlier, the target 20% protective capacity is just a starting point. In order to define what is the optimum level of protective capacity, you need to collect time buffer statistics data. When the buffer's red zone gets penetrated more than 5% to 10% of the time, you will need to create additional protective capacity at least at one if not more non-constraint resources. In case you do not experience any red zone penetrations, your level of protective capacity is most probably excessive, and you can successfully reduce the buffer size (its duration) generating new improvement opportunities. In general, the more variability in the system, the more protective capacity you need. Applying Six Sigma and Lean Manufacturing (Raj and Attri, 2010) techniques can greatly help create process stability within the DBR framework (Mithun et al., 20202; Albliwi , 2014; Alhuraish, 2017).

Figure 1 above shows the first buffer (constraint time buffer) buffering the Drum/Constraint from the variability of upstream resources. Generating this buffer statistics will help size capacity requirements of resources 1 and 2. Recording daily reasons for buffer penetration into red will enable you to determine which machine will need additional protective capacity.

The second buffer (system buffer) is buffering the shipping schedule (due date). The main reason for the system buffer is to absorb the overall system variability – especially after the drum resource. Any order commit date is always an estimate and often wrong because of embedded system variability. Therefore, we need a mechanism that will allow us to mitigate variability impact and provide ability to determine capacity requirements for all flow stream resources. The system buffer allows us to accomplish these objectives.

Accomplishing the above objectives is critical especially from the perspective of ensuring protective capacity and avoiding the wondering bottleneck phenomenon. Not being able to successfully manage this sometimes delicate balance will lower your system overall Throughput.

Required protective capacity could be gained by applying lean manufacturing tools like set-up reduction techniques, using Statistical Process Control (SPC) to control process variability, staggering lunch and other breaks, creating cross functional/trained production teams or by simply buying more capacity if necessary. However, in order to maximize business profitability, creating protective capacity where needed and increasing effective drum capacity without spending money is preferred.

DBR approach is an integral part of FMS and is a prerequisite to enable a Continuous Improvement process in the plant.

3. Drive continuous improvement process based on the main reasons the Drum schedule is not achieved

One of the main assumptions made in this study is that there is a need to develop a universal method thanks to which it would be possible to design production processes in such a way that they are carried out in the most effective manner taking into account the high profitability rate of the type of conducted activity. FMS creates a Continuous Improvement process that uses Pareto Diagrams comprised of reasons hindering the flow through the plant. It prioritizes plant-wide improvement opportunities and reduces system variability in a quick and systematic way (Figure 2 below). The Flow Issue Reporting (FIR) Pareto contains all reported reasons why the schedule attainment was not possible on every scheduled shift. The issues may include mechanical breakdowns, but also shortages, quality, longer than expected set-ups, absenteeism, material handling, etc. It is critical that FIR process is clearly communicated, enforced and reviewed at the end of every shift across the plant.

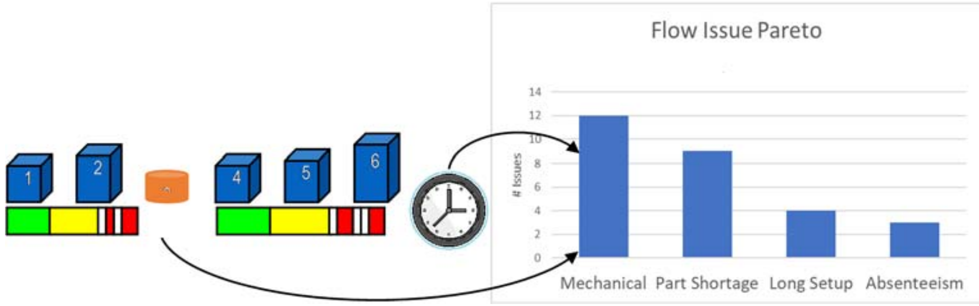

Figure 2. Flow Issue Reporting Process

Source: Own work.

Once the FIR process is in place and improvement opportunities are known, Lean Thinking and Six Sigma principles and tools are used to remove obstacles and create operational improvements (Antony and Banuelas, 2002; Costa et al., 2017). Continuous Improvement team (Kaizen team) meets on a regular basis (often weekly) and decides when and where Lean Thinking and 6 Sigma tools are applied based on the Pareto information. Based on FIR driven priorities, plant performance drastically improves, throughput goes up, service levels increase, and productivity and revenue are maximized.

Once plant performance is stabilized, by breaking dependence (inventory buffers) and having FIR based continuous improvement process in place to reduce process and flow variability, the business is in a much better position to turn its improvement focus towards increasing business profitability through changing product profitability decisions.

4. Base key market, customer and product profitability decisions on the Throughput Economics approach

Cost-per-unit, the world's most popular analysis process, is a devastating and flawed paradigm of traditional business decision-making. Regardless, many organizations still attempt to align their understanding of profitable markets/products with their manufacturing operation's performance using this approach. The cost-per-unit approach supports a simple process for decision-making as it allows managers to use the concept of gross margin or contribution margin to evaluate business opportunities. That is what makes it very popular. However, many managers are aware of the potential distortions and shortcomings of the cost-per-unit approach.

As an example of product profitability decisions consider a company that produces only 2 products: A and B (shown below – Figure 3). It is a 24hr operation, with a labour cost of $10/hr and Operating Expenses of $5,000 per week.

- Product A is produced from Raw Materials costing $14 per unit. This product must be processed on Machine 1, Machine 3 and a Final Assembly operation at the rates specified below. Product A is sold at a price of $50 each and its demand is 100 units per week.
- Product B is produced from Raw Materials costing $12 per unit and requires Machine 1, Machine 2 and the Final Assembly at the rates also specified below. Product B is sold for $60 each and its demand is 50 units per week.

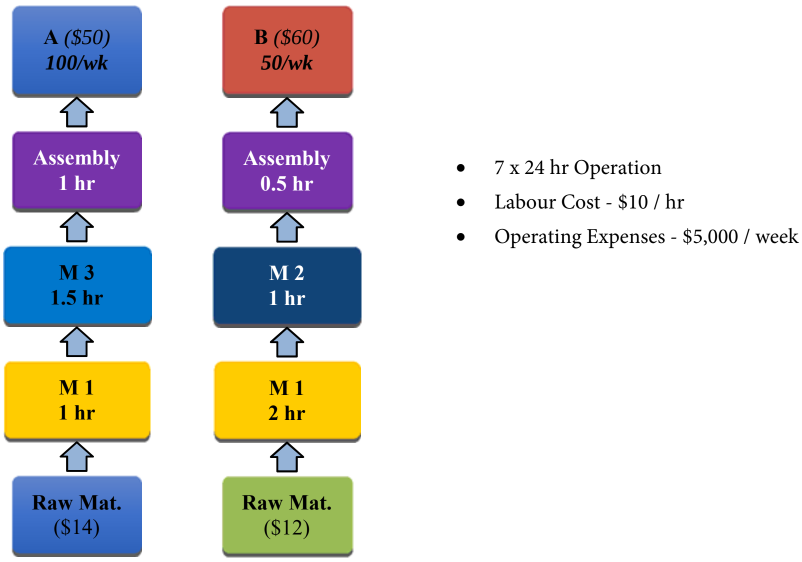

Figure 3. Product Profitability Example

Source: Own work

Table 1. Profit Margin Analysis

	A	B
Price ($)	50.0	60.0
Material ($)	14.0	12.0
Production Time (hr)	3.5	3.5
Labour Cost / hr	10.0	10.0
Material Margin ($)	36.0	48.0
Production Cost ($)	35.0	35.0
Profit Margin ($)	1.0	13.0

Source: Own work.

Which product makes more money for the company? Profit Margin (Sales less Material Costs less Labour) Analysis shown in Table 1 above clearly demonstrates that Product B with a profit margin of $13/unit is the most profitable product *(overhead allocations were omitted to simplify the discussion).*

However, in order to judge how to maximize profitability of this company, we first have to decide which product to prioritize in production, since we do not have enough machine capacity to satisfy the market demand for both products (168 hours available per week in a 7x24 operation vs. 200 hours of M 1 required to produce both A and B – see Table 2 below).

Table 2. Machine Capacity Analysis

	Demand (pcs)	M 1 (hr)	M 2 (hr)	M 3 (hr)	Assembly (hr)	Total (hr)
A	100	100		150	100	350
B	50	100	50		25	175
Total		200	50	150	125	525

Source: Own work.

The business logic suggests that in order to maximize business profitability we should first produce the product with the highest Profit Margin (Product B) and then use the remaining capacity for the other product (Product A). In order to demonstrate the profit impact on the company overall, we need to calculate the net profit associated with producing all B and some A. Since the demand for B is 50 units per week, we need 100 hours (50 x 2 hours) of production capacity for B, leaving only 68 hours open for Product A. This scenario leads to the company generating $4,848 of Material Margin ($ Throughput) every week as demonstrated in the Table 3 below.

Table 3. Material Margin Analysis (prioritize B)

	Demand (pcs)	M 1 (hr)	M 2 (hr)	M 3 (hr)	Assembly (hr)	Price/pc ($)	Revenue ($)	Material ($)	Throughput ($)
A	68	68		102	68	50.0	3,400.0	952.0	2,448.0
B	50	100	50		25	60.0	3,000.0	600.0	2,400.0
Total		168	50	102	93		6,400.0	1,552.0	4,848.0

Source: Own work.

Considering that Operating Expenses for the company are $5,000 per week the resulting business Net Profit is negative $152. This means that maximizing production of the highest Profit Margin Product (B) and satisfying its full demand of 50 units per week will lead to a weekly **profit loss of $152**.

Another interesting question in front of us is to find out what the business profitability would look like if we decided to prioritize product A – the product with a substantially lower profit margin. Under this scenario we can satisfy the entire demand for product A (100 pcs) and dedicate the rest of M1 capacity to product B production. Based on 68 hrs. available we can only produce 34 pcs of product B (2hrs per piece on M1). This scenario leads to the company generating $5,232 of Material Margin every week as demonstrated in the Table 4 below.

Table 4. Material Margin Analysis (prioritize A)

	Demand (pcs)	M 1 (hr)	M 2 (hr)	M 3 (hr)	Assembly (hr)	Price/pc ($)	Revenue ($)	Material ($)	Throughput ($)
A	100	100		150	100	50 zł	5,000 zł	1,400 zł	3,600 zł
B	34	68	34		17	60 zł	2,040 zł	408 zł	1,632 zł
Total		168	34	150	117		7,040 zł	1,808 zł	5,232 zł

Source: Own work.

Considering that Operating Expenses for the company are $5,000 per week the resulting business Net Profit is positive $232. This means that maximizing production of the lowest Profit Margin Product (A) and satisfying its full demand of 100 units per week will lead to a weekly **profit gain of $232.**

How is this possible? Did not the decision to focus on the product with a lower profit / contribution margin just lead to the company generating more net profit? What is going on here? In this example, we have decided to challenge the widely held belief that contribution margin of a product is the best indication of a company's profitability. In most situations it is not. In fact, ***Contribution and/or Profit Margin is a totally arbitrary and completely misleading indicator.***

This conclusion has very large implications on several important sales and marketing decisions, such as: which markets to focus on, which business to accept, how to develop new products that maximize profit, and with which customers to further develop long term relationships.

The profitability of a product, and its associated impact on the net profit of a business, cannot and should not be measured using profit margin. Therefore, what is an acceptable substitute?

FMS uses an alternative approach to understand relative product and market profitability – a Throughput Economics (TE) based approach. Using the same example, we can clearly establish that Machine 1 sets the pace for the entire operation and should be considered a critical resource/drum (i.e. it has the least capacity). Profitability is best determined by calculating the rate of dollar contribution of each product on this critical resource as explained in the DBR section. This is measured by taking the difference between a product's sales price and its totally variable cost (mainly raw materials) and dividing it by the production rate on the critical resource – Table 5 below.

Table 5. Throughput Velocity

	A	B
Price ($)	50.0	60.0
Material ($)	14.0	12.0
Throughout ($)	36.0	48.0
Drum production time (hr)	1.0	2.0
Throughout Velocity ($/hr)	36.0	24.0
Profit Margin ($)	1.0	13.0

Source: Own work.

In all instances, this measurement of product profitability is perfectly aligned with a business' net profit – higher TV for Product A and higher net profit impact.

The TE-based approach with its Throughput Velocity (TV) indicator, has significant implications on plant performance, market focus, pricing evaluation and new product development strategies. Manufacturing businesses need to understand their products' Throughput Velocity (TV) if they are to maximize profit in these challenging times. Using profit margin analysis to accept or reject new business will unavoidably lead to too many wrong decisions – allowing your competitors to take more of your business.

Some of the strategic questions the new process answers include:

- Which market segments are the most profitable?
- Which products make the company the most profit?
- Is it truly possible for some products to lose money?
- How should investment and make vs. buy decisions be analysed?
- At what price should we accept an order?
- How to align your operating costs and plant capacity with market demand?
- On what products to focus its R&D effort?

5. Summary and conclusions

The presented arguments and examples of comparing the results achievable under ‘new’ and ‘old’ approaches, prove the sense of replacing the classic profit margin-based strategy by an approach to profitability based on calculating the rate of dollar contribution of each product on this critical resource, as it was explained in the DBR section. Since Contribution and/or Profit Margin is a totally arbitrary and completely misleading indicator, the new approach which takes into account the difference between a product's sales price and its totally variable cost (and dividing it by the production rate on the critical resource) seems to provide a tool needed to deal with several problems concerning plant performance, market focus, pricing evaluation and new product development strategies.

Using the four key components of FMS, organizations can significantly improve operational and financial performance. Most companies that successfully implement FMS obtain the following benefits:

- Improved flow and reduced operating costs because of their new TOC/Constraints’ Management scheduling tools.
- Increased sales from pricing decisions driven by 80/20 TE-based methodology.
- Released working capital by improved inventory turns as a result of DDR.
- Maximized throughput from a stable plant protected from system variability by the DBR-based operations management approach.
- Increased shareholder value.

In addition, financial benefits often include:

- Throughput/Sales increase of 20%-30%.
- Inventory reduction of up to 50%.
- Lead time reduction of approximately 50%.
- On time delivery improvement up to 99%.
- EBITDA percent of sales increase by approximately 10%.

The application of the discussed solution is not free from the costs incurred by the entrepreneur in the initial period of implementation. Nevertheless, the financial effects related to the implementation of the assumptions of the production management system referred to in the article are disproportionately high compared to the expenditure incurred, which has been repeatedly checked in implementation in business in Poland, Canada and many other countries around the world.

References

ANTONY, J., BANUELAS, R., (2002). Key ingredients for the effective implementation of Six Sigma program, Measuring Business Excellence, 6(4).

ALBLIWI, S., ANTONY, J., LIM, S., VAN DER WIELE, T., (2014). Critical failure factors of lean Six Sigma: A systematic literature review, International Journal of Quality and Reliability Management, 31(9).

ALHURAISH, I., ROBLEDO, CH., KOBI, A., (2017). A comparative exploration of lean manufacturing and six sigma in terms of their critical success factors, Journal of Cleaner Production 164/2017.

BABICEANU, R., SEKER, R., (2016). Big Data and virtualization for manufacturing cyberphysical systems: a survey of the current status and future outlook, Computers in Industry 81/2016.

COSTA, T., SILVA, F. J. G., PINTO FERREIRA, L., (2017). Improve the extrusion process in tire production using Six Sigma methodology, Procedia Manufacturing 13/2017.

DE FREITAS, J., COSTA, H., FERRAZ, F., (2017). Impacts of Lean Six Sigma over organizational sustainability: A survey study, Journal of Cleaner Production 156/2017.

MASON, S., NICOLAY, C., DARZI, A., (2015). The use of Lean and Six Sigma methodologies in surgery: A systematic review, The Surgeon 13/2015,

MITHUN ALI, S., HOSSEN, A., MAHTAB, Z., KABIR, G., KUMAR, S., ADNAN, Z., (2020). Barriers to lean six sigma implementation in the supply chain: An ISM model, Computers & Industrial Engineering 149/2020.

RAJ, T., ATTRI, R., (2010). Quantifying barriers to implementing Total Quality Management (TQM), European Journal of Industrial Engineering 4(3)/2010.