# Resource Efficiency and Sustainable Management of Secondary Raw Materials

A Bilateral Indo-German Project

## Focused Management as success factor for resource efficiency

### Manual for business counsellors

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## 0. Introduction

### Global call for resource efficiency

The message from UNEP's report "Resource Efficiency: Potential and Economic Implications" (2016) is clear: 84 billion tonnes of materials were extracted and used globally in 2015 – including ores, minerals, fossil fuels and biomass. In a little more than one century (1900 - 2005), the amount had increased eightfold, twice the rate of population growth.

As a consequence, UNEP calls for decoupling of resource use and associated environmental impacts from the growth of economic output as an indispensable prerequisite for reaching the Sustainable Development Goals and the Paris Agreement, keeping the increase of global temperatures below 2°C, or even better, under 1,5°C.

The benefits of a resource efficient economy are manifold: to secure future resource availability, increase predictability in times of increasing and volatile resource prices, prevent the present unsustainable use of renewable resources and the environmental impacts of resource extraction and use.

### Rethinking resource efficiency strategies for SME

It sounds logical: Applying resource efficiency measures in companies is not only good for the environment - cost savings from material and energy may pay for themselves. However, reality shows a completely different picture: according to a study commissioned by VDI-ZRE in 2015, only 27% of SME representatives believed that existing resource efficiency potentials in their branch were fully exploited. In developing countries and emerging economies, the situation is certainly not more encouraging. Why is that so?

Resource efficiency cannot be taken for granted! As long as business is going well, there is limited pressure to change the business-as-usual way. If the business goes down, there is usually not enough time and money for longer lasting improvements, because short term crisis management is needed.

Even those companies that recognize the potential, sooner or later are confronted with the fact that some of the savings can only be attained through substantial investments in process improvements resulting in long pay-back periods. Lacking own financial means, such companies depend on loans at high interest rates or are frequently not even bankable so that they will refrain from investments.

Another lesson learnt from management concepts focusing on savings in energy, material, and water is that after capturing the low hanging fruits, improvement become more difficult and even resistance comes up when cost reduction policies are applied to the personnel.

### Turning around a resource efficiency strategy for SME

As a consequence, GIZ and VDI-ZRE used a different strategy: instead of arguing that savings can be achieved **through** resource efficiency measures, a methodology was chosen which focuses on increasing productivity and profitability **for** resource efficiency, combining the benefits from different management approaches:

- For the holistic analysis and prioritization of measures, Constraint Management (Theory of Constraints – TOC) was introduced to ensure that improvement efforts are focused on those areas of the company that yield the largest benefit (throughput).
- The tools VDI-ZRE are applied for detecting savings in resources follow the logic of Lean Management, focusing on waste reduction along the production process and the supply chain.

This “methodological hybrid” is nothing new in global business: many companies worldwide have already successfully introduced the combination of TOC, Lean and Six Sigma methods: Mazda, IBM, Delta Airlines, TATA Industries, Lufthansa Technik just to mention a few of the big players. In India, Bharat Bijlee (BBL), Godrej Security Solutions, Fleetguard Filters, Elecon Engineering, Dhanuka Agritech, Paragon Textile Mills, and JCB India that combined their quality management systems with TOC.

As the approach is relatively new in development cooperation, the following document provides information about the methodological background, referring to TOC as “*Focused Optimization Management – FOM*”. While part 1 describes the methodological basis in general, part 2 introduces examples on how to calculate the relevance of investments from a holistic perspective focusing on throughput. Addressing productivity and profitability first departs from the pressing needs SMEs are experiencing. It helps them to achieve a more resilient level where investments from their own profits become affordable more easily. During this initial process, positive impacts on resource efficiency already take place but are primarily achieved indirectly as “by-products”, paving the ground for major investments in resource efficiency. This is then the moment when the expertise of organizations like VDI-ZRE becomes vital because they provide the technical knowledge that is important for assessing the pros and cons of different technological efficiency options.

The methodological approach was developed under the umbrella of the Indo-German programme on “Resource Efficiency and Management of Secondary Raw Materials”. After training business counsellors from the ACMA Centre for Technology (ACT), it was applied in member companies of the Automotive Component Manufacturers Association of India (ACMA).

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## PART 1: FUNDAMENTAL ASPECTS

Focused Optimization Management (FOM) is based on the Theory of Constraints as the main source. The central idea behind it is the fact that every system is limited in its performance by existing constraints. In order to improve the results of a system, the existing constraints must be overcome.

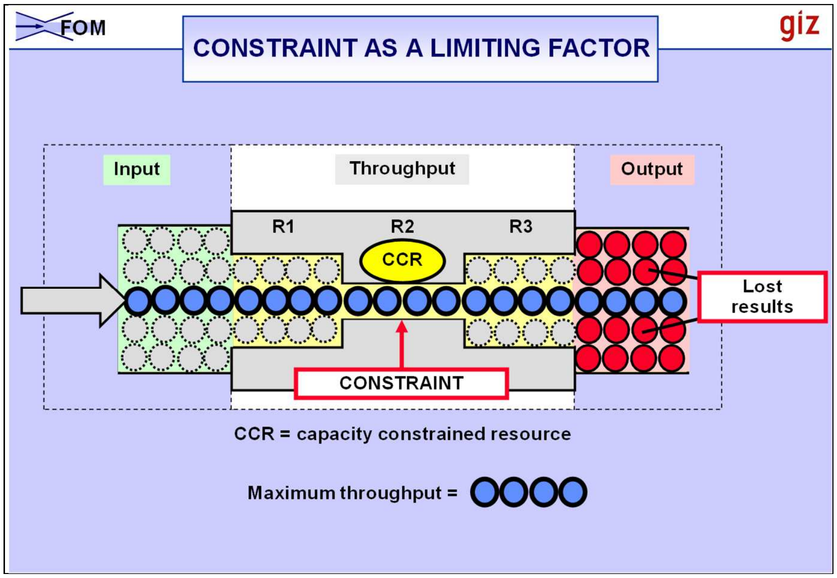


Figure 1

In the given example there is a system with 3 resources where R2 is the bottleneck that limits the throughput and in the end the possible output. It does not make any sense to improve the productivity of resources R1 and R3 as long as R2 has not been improved. This is why the focus of attention should always be directed towards the constraint if we want to obtain substantially better results.

| Important facts: |
| --- |
| Every system has at least one constraint, so there is no system without a constraint. |
| The constraints define the performance of a system. |

The ideal state of a system is the one that can exactly satisfy the demand for a product or service without delivering more or less than necessary. As a consequence, the existing constraints must be dealt with in such a way, that the throughput is maximized.

### Throughput as the main measurement of performance

Throughput is defined in FOM as the velocity of value generation, which can be stated in terms of money (for-profit enterprises), or goal units (non-profit organizations). In contrast to the concept of improving the physical flow of products or services (e.g. Lean Production), throughput is characterized by the flow of profit contribution that is attached to these products or services like shown in figure 2.

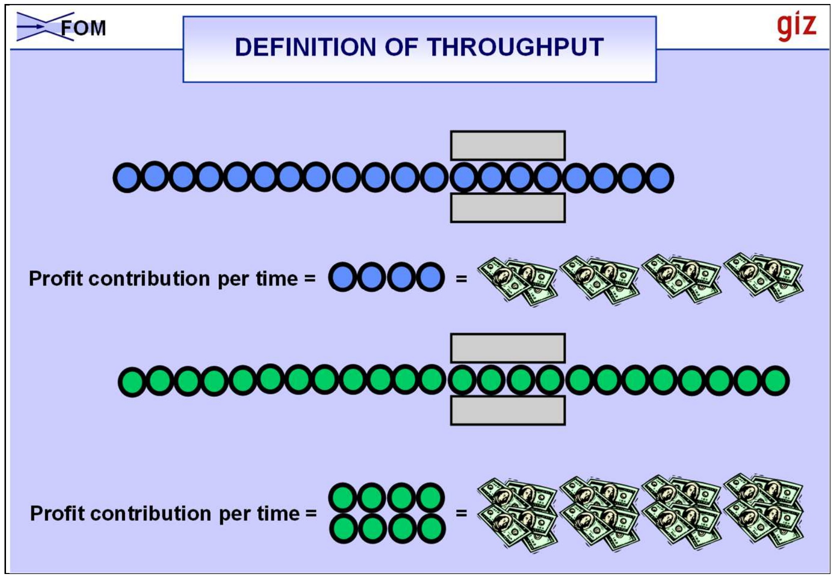


Figure 2

If a product A with a profit margin of $4/unit can go through the constraint (and ultimately the system itself) at a rate of 10 units/hour, the generated throughput is $40/hour. If a product B with a profit margin of $2/unit can go through the constraint at a rate of 30 units/hour, the generated throughput is $60/hour. Although product B has a lower profit margin than A, it can generate more profit contribution/hour. Usually A is considered to be the more profitable product without applying the FOM perspective, thus leading very often to faulty decisions.

Important definition:

Throughput for enterprises is the speed of generating money.

Since throughput is the main performance measurement for for-profit enterprises, all other measurements in such a system must be in line with the supreme goal of generating more profit, thus simplifying the control of an enterprise.

**Types of constraints**

In essence, there are two main types of constraints: physical and non-physical constraints. As can be seen in figure 3, the above constraints may be either internal or external. Interestingly, experience shows that most constraints are internal and even external ones may have an internal origin. The advantage is that it is usually easier to deal with internal than external constraints.

The physical constraints are usually those related to resource capacities. The more difficult to detect and to tackle constraints are typically non-physical constraints related to policy and decision making. Most constraints have their origin in this area. Even physical constraints may have a non-physical origin. This might be the case if a policy decision causes a bottleneck in the production line. FOM has developed special tools to diagnose and look for solutions for this type of constraints.

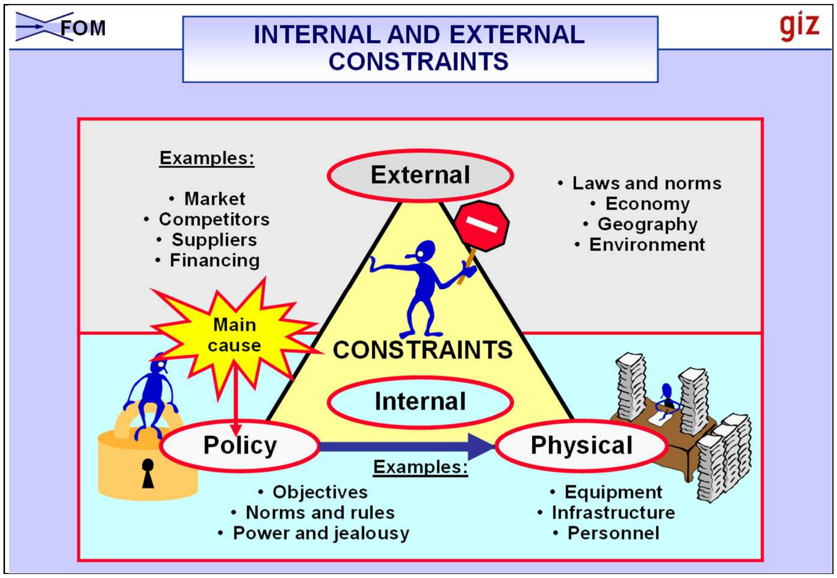


Figure 3

## Constraints in systems

An enterprise or an organization are always systems and must be dealt with in a systemic way. A system is a collection of interdependent links that interact to produce an output in the form of products or services. Such a system may be represented in a simplified way by the analogy of a chain as in the figure below.

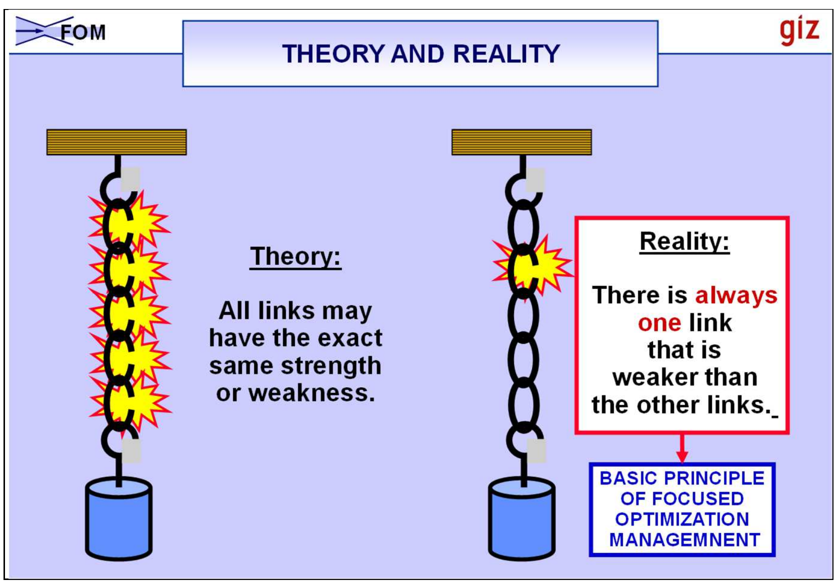


Figure 4

Many improvement methods part from the idea that in a system (=chain) it does not matter where an improvement is made since the results will show up somehow in the bottom line. This is partially true for cost cutting measures, since it is the equivalent of reducing the weight of the whole chain. The apparent assumption for such reasoning is that in theory, all links must have the same strength or weakness and therefore it is indifferent where an improvement takes place. In reality, however, there is always a link that is weaker than the others. If the strength or performance capacity of a system (=chain) should be improved, this will only be effective when the weakest link is reinforced or changed. In consequence, if one wants to obtain a decisively better performance of a system, one must always focus on the weakest link. This is the real essence of FOM.

Important fact:

Decisive performance improvements can only be obtained while focusing on system constraints (= weak links).

According to the chain analogy, once the first constraint has been eliminated, a new constraint will appear. Again, the new constraint has to be dealt with until it is no longer a constraint. As it can be seen in the figure below, constraints appear in a certain sequence. One does not have to wait until the constraints appear – their appearance can be predicted and thus it is possible to plan corresponding actions or investments well in advance.

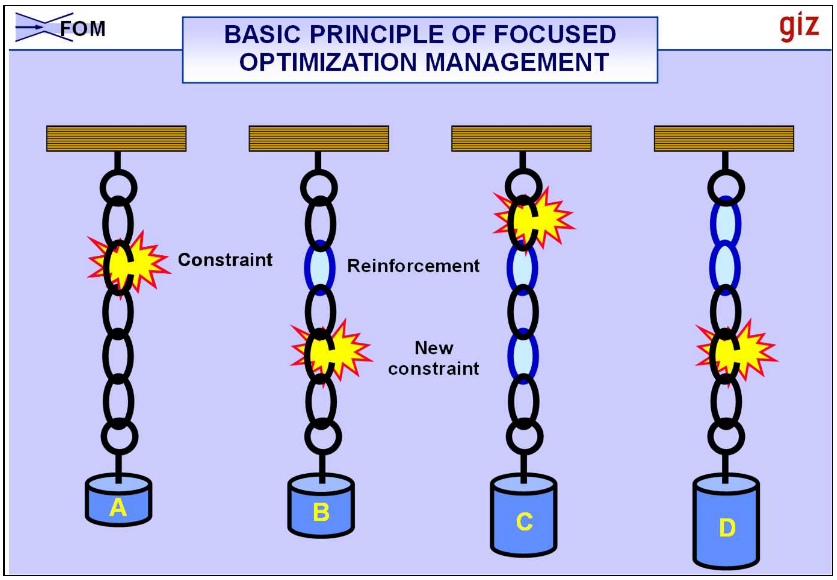


Figure 5

**Focusing process**

FOM uses a 5 step focusing sequence to deal with system constraints.

Step 1: Identify the active constraint.

Even though there are many constraints in a system, usually there is only one constraint at a given point of time that limits the whole system. This weakest link is called the active constraint and must be identified before being able to take further actions.

Step 2: Exploit the constraint to its maximum.

In many cases the constraint is not working to the maximum of its capacity. In such a situation action has to be taken to reach the required maximum to the point where it is no longer a constraint. This can be achieved, for example, through additional operating time. Exploitation does not require investments in the constraint.

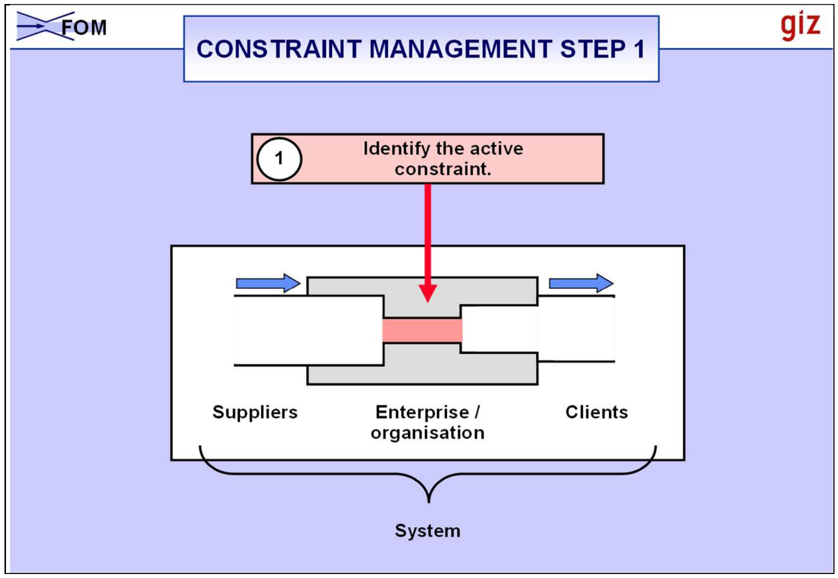


Figure 6

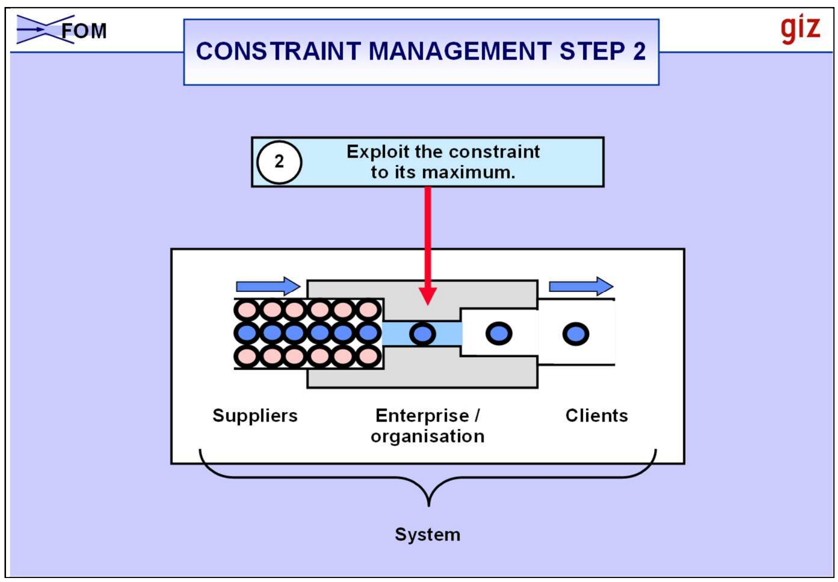


Figure 7

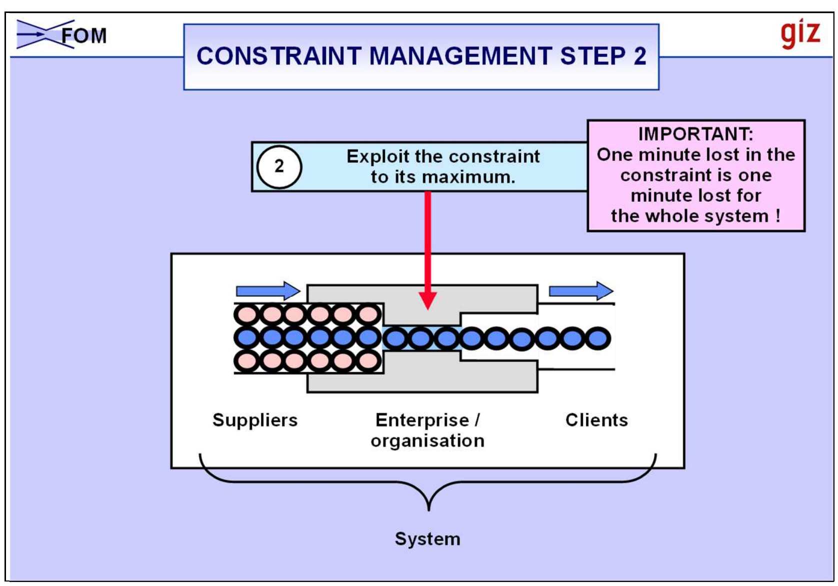


Figure 8

Important fact:

The active constraint is the only resource that must work with the highest efficiency within a system.

One minute that is lost in a constraint is lost for the whole system.

Step 3: Subordinate the non-constraints to the constraint.

The resources which are not a constraint must work at the pace of the active constraint since otherwise unnecessary inventories will build up in front of the constraint. The non-constraints must be subordinated or synchronized to the constraint. This step must go together with step 2.

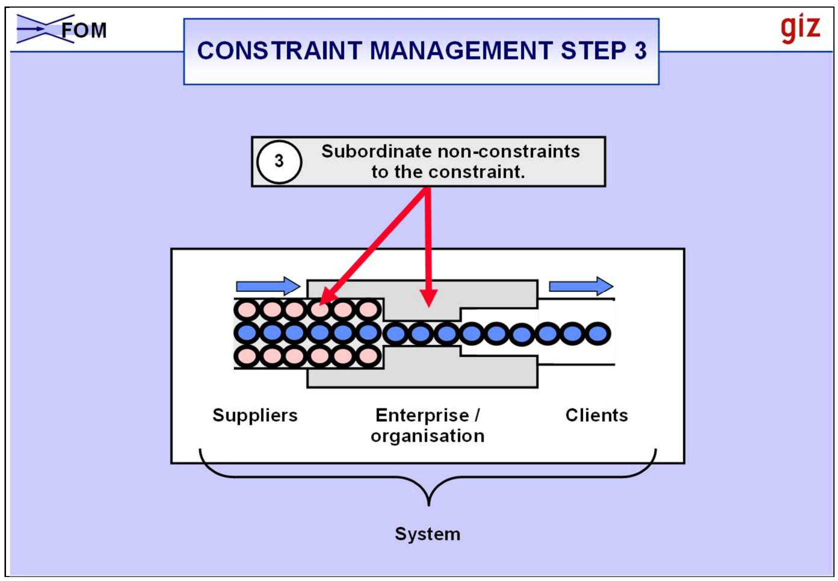


Figure 9

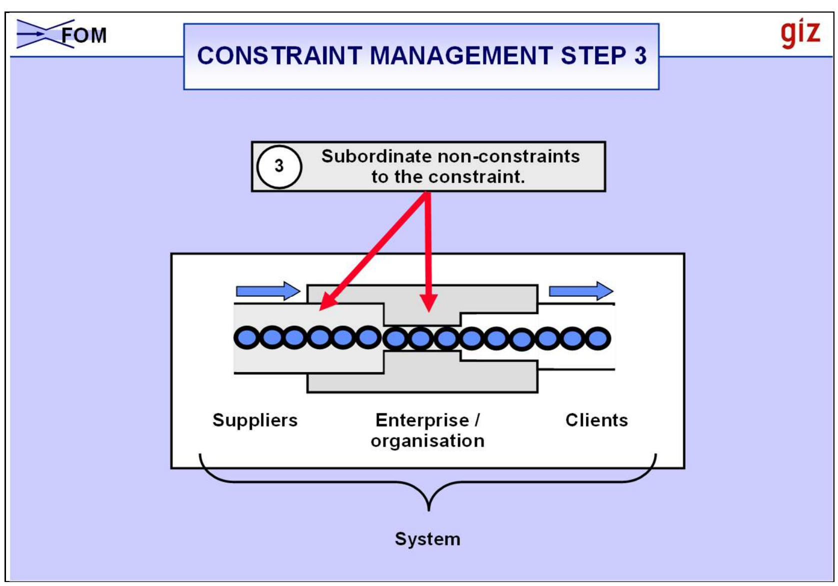


Figure 10

Only if these 3 initial steps will not get rid of the constraint, then we should go to step 4.

Step 4: <u>Elevate the constraint.</u>

While the exploitation step 2 did not require investments, step 4 will require investments to elevate or expand the capacity of the existing constraint. Elevation usually implies investment in technical changes or new / additional equipment.

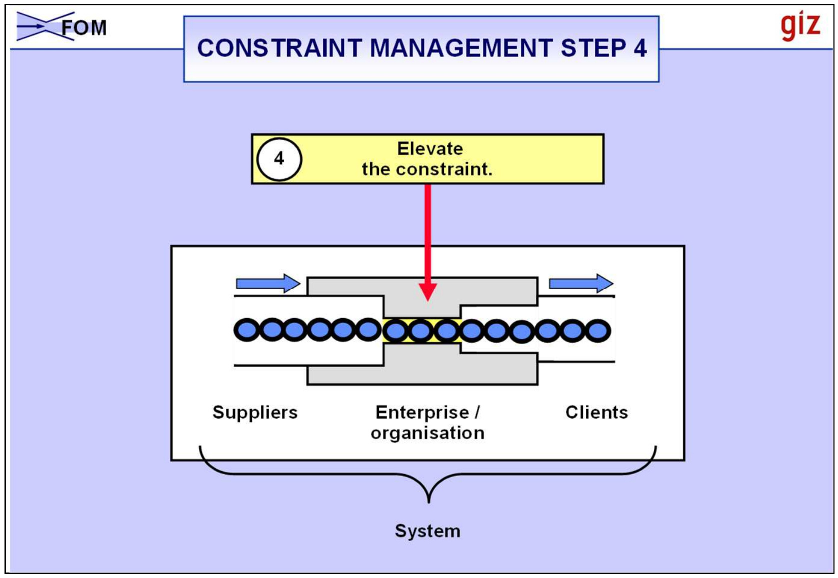


Figure 11

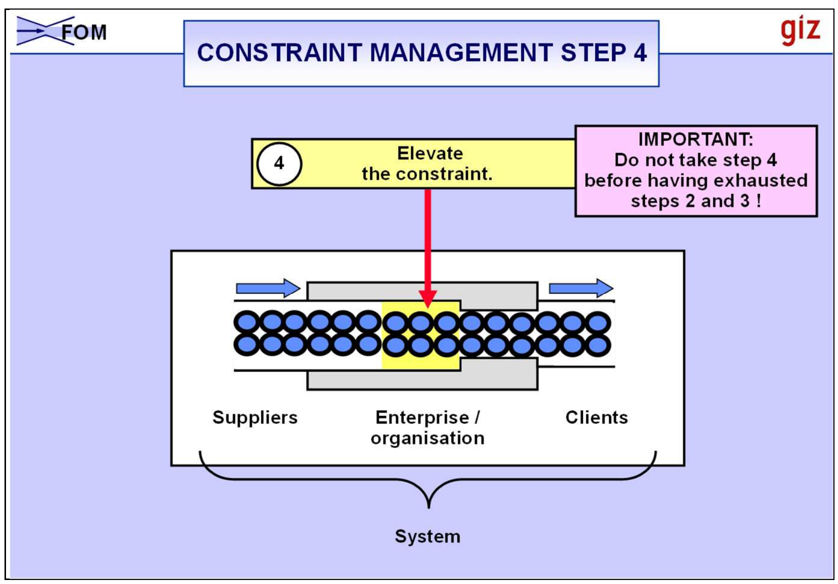


Figure 12

Step 5: <u>Go back to step 1 and do not let inertia become the new constraint.</u>

Once the constraint has been elevated, according to the chain analogy of figure 5, a new constraint will appear sooner or later. Then one has to go back to step 1 and identify the new active constraint and start the process all over again. If this is done again and again it will become a process of ongoing improvement.

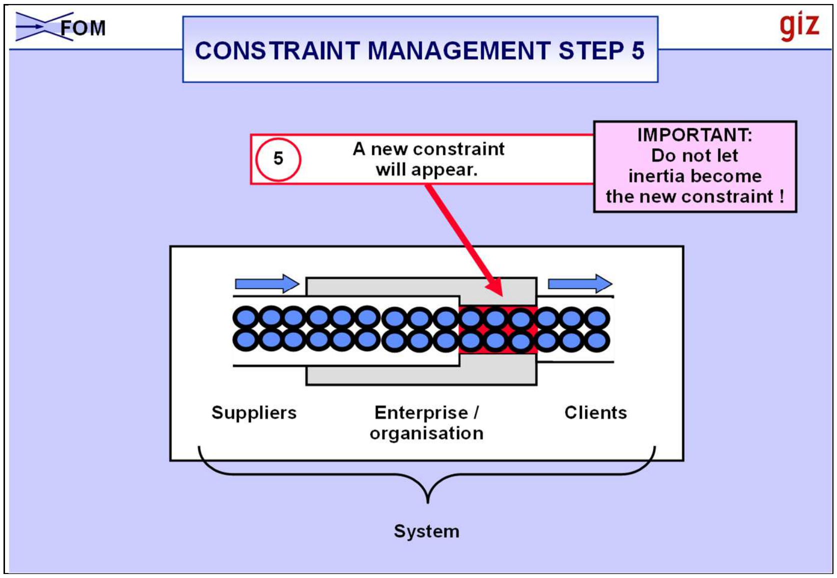


Figure 13


Figure 14

The 5 Focusing Steps are a fundamental as well as one of the most important tools of FOM to manage operations.

**Testing the economical feasibility of improvements**

Whenever an active constraint is identified, the following questions should be asked before taking any action.

1. <u>Can throughput be increased?</u>

   Ideally the envisioned action will lead to an increase in throughput. However, if this is not feasible, than at least the next questions should be asked.

   The increase of throughput should always be the primary focus.

2. Can inventories be reduced?

   If the action leads to a reduction of finished goods, work-in-process or production input inventories then the liquidity is improved as well as the expenses of holding inventories are reduced.

3. Can expenses be reduced?

   If the action leads to a reduction of expenses (not calculated costs) then the profitability is improved.

   The difference between expenses and costs is as follows: expenses are "out-of-pocket money" that is really spent whereas costs are calculated figures that do not necessarily reflect the real expenses.

If none of the above questions can be answered in a positive way, the envisioned action will not improve the economical results of the enterprise and should therefore be discarded. In such a case, a new alternative must be searched for.

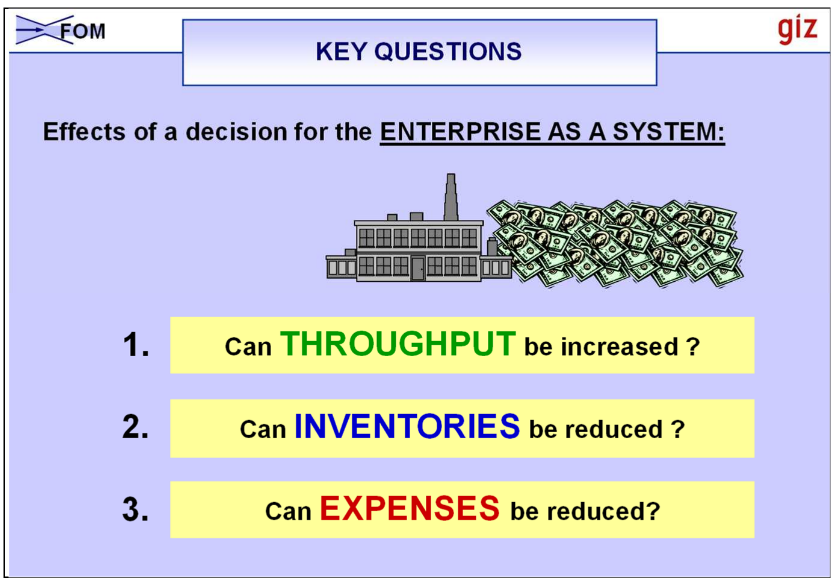


Figure 15

**Compatibility of Focused Optimization Management and Lean Production**

Lean Production has its origins in the Toyota Production System (TPS) and focuses primarily on eliminating waste from the manufacturing process. Although the original purpose of TPS was to improve customer satisfaction to increase sales, nowadays it is often used to bring down costs. As a result of eliminating waste, the physical production flow becomes smoother and the manufacturing costs are reduced both leading to a higher profitability. From the viewpoint of Lean, an organization is a collection of parts that can be systematically broken down, individually improved and put back together.

Focused Optimization Management (FOM) is geared towards identifying and removing constraints that limit throughput. In contrast to the physical production flow of Lean, throughput is measured in terms of flow of profit contribution or product contribution margin per time unit. According to FOM, an organization is a system of interrelated parts that can only be improved systemically by focusing on the constraint.

Both methodologies have a strong focus on customers and are capable of transforming companies to be faster, stronger, and more profitable. In essence, FOM and Lean are both systematic methods for improving manufacturing effectiveness. Due to this common ground, FOM and Lean are perfectly compatible if correctly combined.

In principle, FOM and Lean can coexist to a certain extent in parallel. However, a high degree of synergy and effectiveness can only be achieved by using Lean in conjunction with an FOM system perception. The best example is the combination of Lean tools with the aforementioned FOM 5 focusing steps for physical constraints:

| FOM Focusing Steps | | Applicable LEAN Tools |
|---|---|---|
| Step 1 | Identify the active constraint. | • Value Stream Mapping<br>• Gemba |
| Step 2 | Exploit the constraint to its maximum. | • 5S<br>• Visual Factory / Andon<br>• Standardized Work<br>• Kaizen<br>• TPM<br>• SMED |
| Step 3 | Subordinate the non-constraints to the constraint. | • Kanban<br>• Line Control |
| Step 4 | Elevate the constraint. | • Kaizen<br>• TPM<br>• SMED<br>• Poka-Yoke<br>• Jidoka |
| Step 5 | Go back to step 1 and do not let inertia become the new constraint. | |

Figure 16

A more detailed description of the most important applications of Lean tools in the context of FOM is given below.[1]

Step 1: Identify the active constraint.

Lean Production provides an excellent tool for visualizing the flow of production (Value Stream Mapping) as well as a philosophy that promotes spending time to observe what is actually happening at the plant floor (Gemba).

*Value Stream Mapping*

VSM visually maps the flow of production (current and future states) using a defined set of symbols and techniques.

- Provides a foundation from which to work when identifying the constraint. For example, the cycle time of each stage can be marked on the map.

*Gemba*

Gemba is a way to observe and 14nalyse processes at the shop floor level. This promotes a deep and thorough understanding of real-world manufacturing issues – by first-hand observation and by talking with plant floor employees.

- Walking the plant floor, observing production, and interacting with employees can be a very effective way to gather information that helps identify the constraint.

Step 2: Exploit the constraint to its maximum.

Lean Production strongly supports the idea of making the most of what you have, which is also the underlying theme of FOM for exploiting the constraint. For example, lean teaches to organize the work area (5S), to motivate and empower employees (Visual Factory / Andon), to capture best practices (Standardized Work), and to brainstorm incremental ideas for improvement (Kaizen).

*5S*

5S is a program for eliminating the waste that results from a poorly organized work area. It consists of five elements: Sort (eliminate that which is not needed), Set In Order (organize the remaining items), Shine (clean and inspect the area), Standardize (create standards for 5S), and Sustain (consistently apply the standards).

- Creates a foundation for better performance at the constraint.
- Enables faster identification of emerging issues at the constraint.

*Visual Factory / Andon*

Visual Factory is a strategy for conveying information through easily seen plant floor visuals.

- Andons display constraint production metrics and status in real time and enable operators to bring immediate attention to problems so they can be instantly addressed.

- Reduces reaction time to stoppages by instantly alerting operators to intervene.
- Increases focus by using visuals to reinforce the importance of the constraint.

*Standardized Work*

Standardized Work captures best practices in work area documents that are consistently applied by all operators and that are kept up-to-date with the current best practices.

- Improves throughput by consistently applying best practices at the constraint.
- Reduces variation by applying standardized procedures at the constraint.
- Ensures that all operators setup and run the constraint in a repeatable way.

*Kaizen*

Kaizen provides a framework for employees to work in small groups that suggest and implement incremental improvements for the manufacturing process. It combines the collective talents of a company to create an engine for continuous improvement.

- Provides a proven mechanism for generating ideas on how to exploit the constraint.
- Identifies “quick win” opportunities for improving throughput of the constraint.
- Engages operators to work as a team and to think critically about their work.

Step 3: <u>Subordinate the non-constraints to the constraint.</u>

Although FOM offers such TOC tools as DBR (Drum-Buffer-Rope) and Buffer Management, it might be adequate in some cases to apply Lean Production techniques for regulating flow (Kanban) and synchronizing automated lines (Line Control) in order to subordinate and synchronize to the constraint.

*Kanban*

Kanban provides a framework for employees to work in small groups that suggest and implement incremental improvements for the manufacturing process. It combines the collective talents of a company to create an engine for continuous improvement.

- Offers simple visual techniques for controlling the flow of materials.
- Synchronizes material usage at the constraint with material usage in the upstream process by controlling when new materials are released into the process.

*Line Control*

Line Control is a sophisticated technique used with synchronous automated lines, such as FMCG (Fast Moving Consumer Goods) lines, which slaves non-constraint equipment to the constraint in such a way as to increase overall system throughput.

- Provides an effective alternative to traditional TOC Drum-Buffer-Rope for FMCG lines.
- Optimizes constraint and non-constraint running speeds to maximize throughput and reduce the frequency of minor stops.
- Reduces startup delays on the constraint by synchronizing equipment startup.

Step 4: Elevate the constraint.

Lean Manufacturing techniques for proactively maintaining equipment (TPM), dramatically reducing changeover times (SMED), building defect detection and prevention into production processes (Poka-Yoke), and partially automating equipment (Jidoka) all have direct application when elevating the constraint. TPM and SMED can also be viewed as exploitation techniques (maximizing throughput using currently available resources); however, they are fairly complex.

*TPM (Total Productive Maintenance)*

TPM offers a holistic approach to maintenance that focuses on proactive and preventative maintenance to maximize the operational time of the constraint (increasing up time, reducing cycle times, and eliminating defects).

- Reduces the frequency of constraint breakdowns and minor stops.
- Provides operators with a stronger feeling of “ownership” for their equipment.
- Enables most maintenance to be planned and scheduled for non-production time.
- Targets quality issues by finding and removing the root causes of defects.

*SMED (Single-Minute Exchange of Dies)*

SMED is a method for dramatically reducing changeover time at the constraint. As many steps as possible are converted to external (performed while the process is running) and remaining steps are streamlined (e.g. bolts and manual adjustments are eliminated).

- Increases usable production time at the constraint.
- Enables smaller lot sizes, resulting in improved responsiveness to customer demand.
- Enables smoother startups, since a simplified and standardized changeover process improves quality and consistency.

*Poka-Yoke*

Poka-Yoke (also referred to as “mistake proofing”) designs defect detection and prevention into equipment with the goal of achieving zero defects.

- Reduces the number of defects going into a constraint (which is also very important in post-constraint resources).

*Jidoka*

Jidoka means “intelligent automation” or “automation with a human touch”. It recognizes that partial automation is significantly less expensive than full automation. Jidoka also emphasizes automatic stoppage of equipment when defects are detected.

- In some cases, the constraint cannot be broken without significant capital investment. Jidoka can provide valuable guidance on equipment design and upgrades.

Step 5: Go back to step 1 and do not let inertia become the new constraint.

FOM and Lean are both based on continuous improvement processes and therefore share a common philosophy.

As it could be seen, Focused Optimization Management and Lean Production can be very well used together. Instead of using Lean Tools indiscriminately through the whole production process, FOM offers a perfect guideline where to apply Lean tools with which priority to achieve even more faster and beneficial results while concentrating on constraints.

[1] Based on ideas of Vorne Industries Inc.

## PART 2: ECONOMIC INVESTMENT EVALUATION

Serious mistakes can be made when trying to decide on possible investments in the traditional way. However, if FOM criteria are applied for the evaluation, the most advantageous investments can be identified with a high degree of certainty. The following example will show, how to proceed by using FOM throughput based calculations.

Let us suppose that we have to decide among 2 investment suggestions in a production system: machine A and machine B. Since the budget is limited to $ 500,000, only one of the two machines can be bought for the time being.

As we can see from the data below, the production per year is 30,000 units of a given product P. On the other hand, the yearly demand for product P is 45,000 units/year, which means that the company is forgoing possible profits coming from the missing 15,000 units.

FOM — INVESTMENT EVALUATION — giz

| Investment in new machine: | A | B |
|---|---|---|
| • Investment = | $ 80,000 | $ 500,000 |
| • Useful life = | 10 years | 10 years |
| • Efficiency increase = | 100% | 5% |
| • Actual production time = | 8 min. / unit | 10 min. / unit |
| • Future production time = | 4 min. / unit | ≈ 9.5 min. / unit |
| • Time savings = | 4 min. / unit | ≈ 0.5 min. / unit |
| • Production / year = | 30,000 units | 30,000 units |
| • Operating costs* = | $ 40 / hour | $ 40 / hour |

* 25% direct labour expenses / 75% overhead expenses

Figure 1

FOM — INVESTMENT EVALUATION — giz

| Investment in new machine: | A | B |
|---|---|---|
| • Actual capacity / year = | 37,500 units | 30,000 units |
| • Actual production of P = | 30,000 units / year | |
| • Demand of product P = | 45,000 units / year | |
| • Available production time = | 5,000 h / year | |
| • Sales price of P = | $ 500 / unit | |
| • Raw material costs = | $ 350 / unit | |
| • Available investment resources = | $ 500,000 | |

Figure 2

At first glance, machine A seems to be the more promising investment, since an efficiency increase of 100% is obtained through an investment $80,000 versus only 5% for an investment of $500,000 in a new machine B. Nonetheless, a more detailed analysis is needed to determine which is really the best investment.

Rule 1:

Identify the system's active constraint. Make sure you know the functioning of the entire system.

According to FOM, in a first step one must identify the active constraint of a system. From the given data, it becomes clear that the apparent constraint, which limits the production output, is the current machine B with a capacity of 30,000 units/year. Although the current machine A is also a constraint given its limited capacity of 37,500 units/year, it is not an active constraint like B and therefore must not be taken into consideration at this point of time.

Even though B seems to be the real constraint, one must be sure that no more important constraints exist within the system. Therefore one must look at the complete picture of the system.

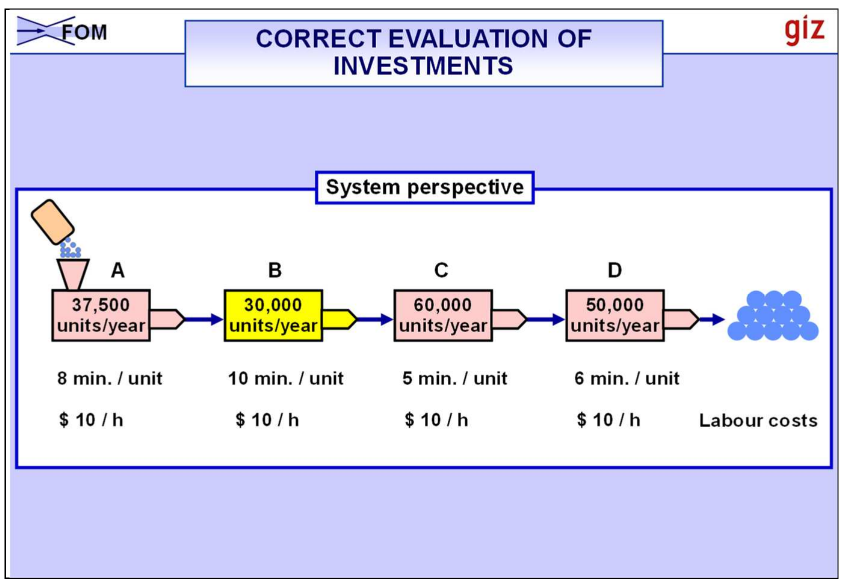


Figure 3

In the current example, the actual system consists of 4 interdependent machines. Only now we can be sure that B is the system's active constraint and start with our calculations to determine the investment benefits. Since machine is not an active constraint or weak link, an investment in a new machine A would not improve the system's output situation at this point of time. Investing in A, C, or D would be a nuisance in this instance.

Rule 2:

Only invest where throughput can be increased the most.

Due to the fact that B is the active constraint, the efficiency increase of 5% becomes an effective increase of 5% production output for the whole system equivalent to 1,500 units/year.

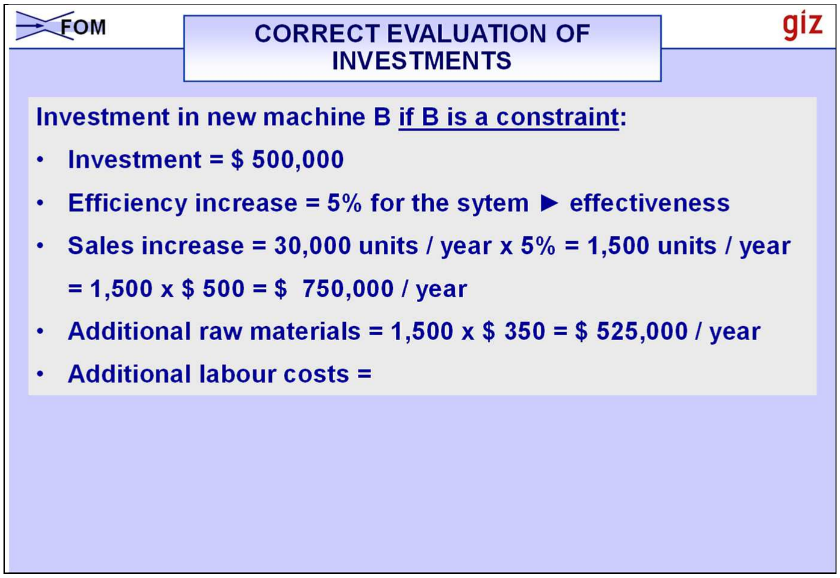


Figure 4

Since the new machine B is now producing 1,500 additional units, the production at the other machines must be increased as well, which in turn requires additional labour. In order to come up with the right calculations, one must consider only the incremental or variable costs. Therefore, in our example, the real operating costs are $10 since the machine operators are paid on an hourly basis. The overhead costs will usually not vary in such a case, therefore the $40 / hour used in traditional calculations are not applicable.

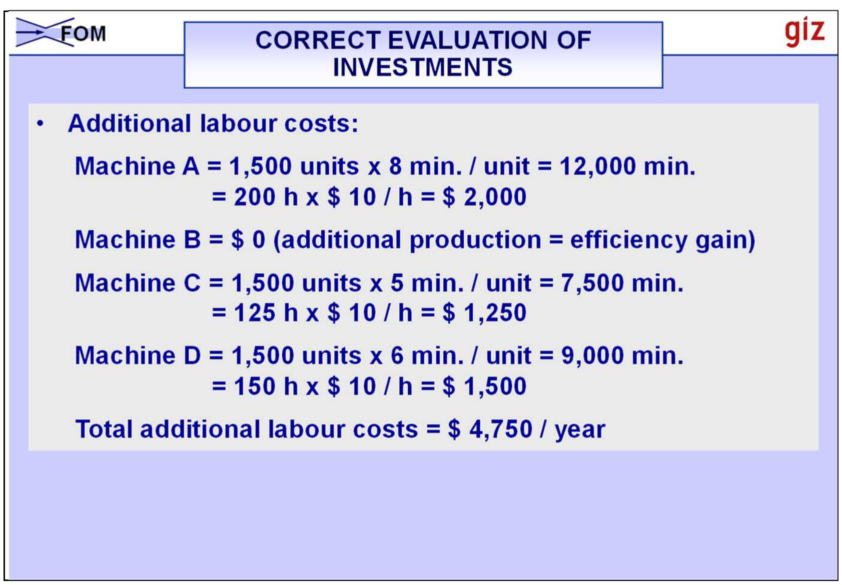


Figure 5

As we can see from the following calculations, the incremental gain or additional throughput from investing in a new machine B amounts to $220,250/year and the investment will be recovered in 2.27 years. Usually the payback period is used as a basis for investment decisions – a shorter payback period will lead to a better investment. However, the relevant factor should be the throughput and not the payback period.

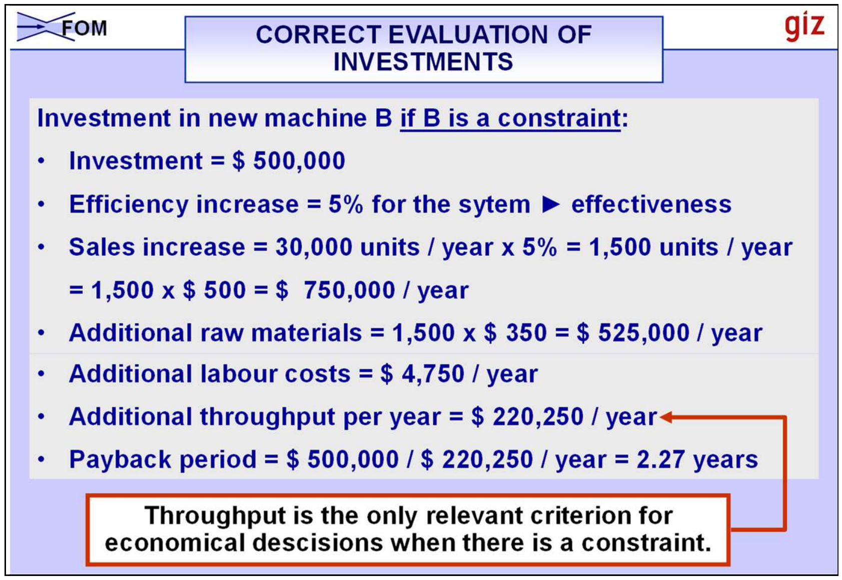

Figure 6

In most cases it is very difficult to calculate the useful life span of a machine since long term forecasts about the usage are not precise enough. Therefore, the corresponding depreciation values may distort the decision. Nevertheless, if we want to take the wear and tear of the equipment into account, we must deduct the technical depreciation (not the fiscal depreciation) from the additional benefit. Since the new machine B has an estimated useful life of 10 years, we can assign a yearly depreciation rate of $50,000 ($500,000 / 10 years). In this case the additional throughput of investment B will be $170,025/year.

**Throughput perspective vs. cost saving perspective**

Often efficiency is seen as the way to produce something at a lesser cost. Therefore, many investment calculations focus on cost saving as the primary target. The following calculations will show the results for investments in A and B under this perspective.

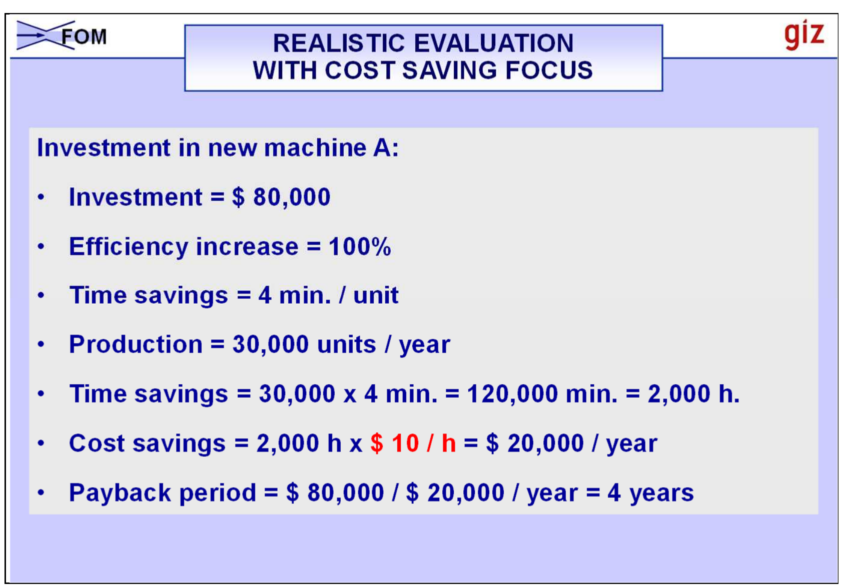

Figure 7

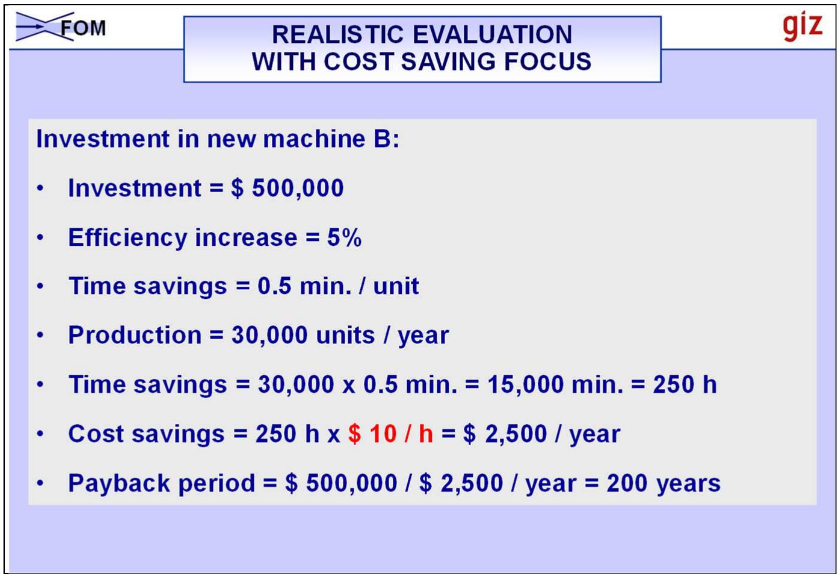


Figure 8

In the present example, the cost savings are entirely labour costs. To a large extent, labour costs often offer the biggest saving opportunities. However, saving on labour is a debatable strategy when it comes to the social responsibility of job creation.

As it can be easily seen, under the cost saving perspective the investment should go to machine A since machine B will only recover its investment after 200 years.

The above example shows how tricky investment calculations can be when system constraints are not taken into account as suggested by FOM. Due to the fact that there is no system without minimum one constraint, the FOM perspective is the correct way to evaluate economic decisions.

The difference between the throughput and the cost-saving perspective is summarized below.

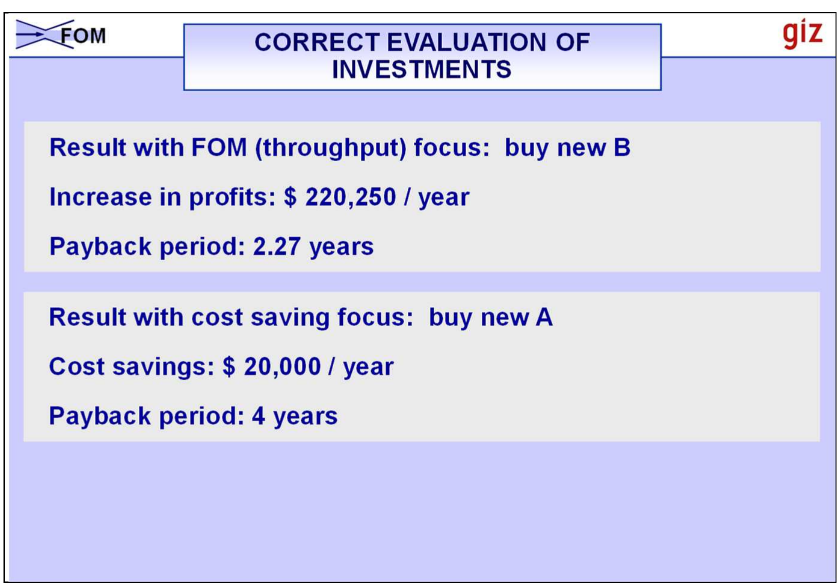


Figure 9

In the example the difference between the investments is $200,250/year of additional gross profit. This profit should be used to further improve the operation in terms of overall resource efficiency.

Important conclusion:

Cost-saving calculations should always be contrasted with constraint-based throughput calculations before making an investment decision.

**Designing an investment strategy based on constraints**

According to the chain analogy, once the weakest link has been made stronger, a new weak link or capacity constrained resource (CCR) will appear. A new investment should therefore focus on the new constraint.

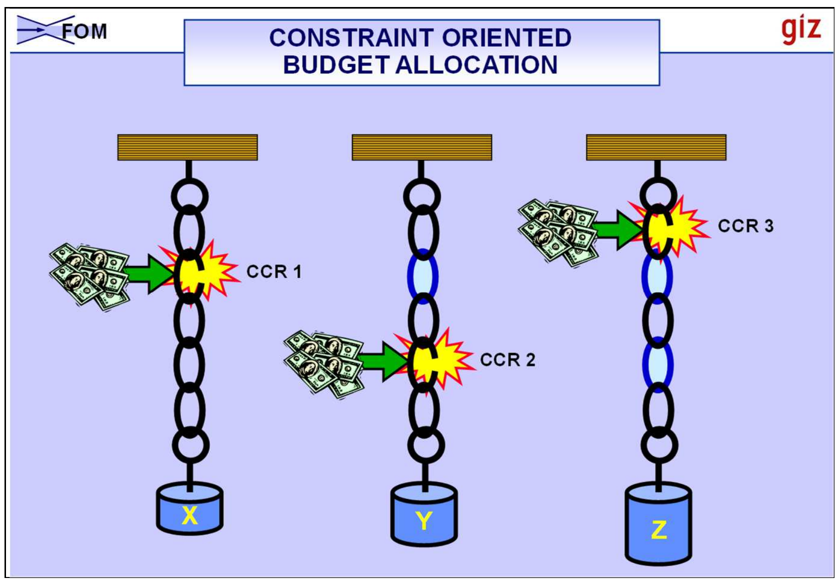


Figure 10

In the given example, the new machine B is still the active constraint since its capacity of 31,500 units/year is below the capacity of 37,500 units/year of machine A, which is the next potential constraint according to figure 3.

Assuming that there is enough space to operate the old as well as the new machine B, the old machine B will provide enough capacity to reach the next limiting level of 37,500 units/year. Under this circumstance, the old machine B is reactivated. Again, the production levels of machines A, C, and D as well as old B have to be increased. The results are shown in figures 11 to 13.

According to the calculations, old machine B is giving us an additional throughput of $871,000/year without any further investment. In this case we are “exploiting” the existing resources, which is totally consistent with the 5 Focusing Steps of FOM.

FOM

**CORRECT EVALUATION OF INVESTMENTS**

giz

Reactivation of old machine B if new B is still a constraint:

- Additional investment = $ 0
- Usable capacity increase = 6,000 units / year
- Sales increase = 6,000 x $ 500 = $ 3,000,000 / year
- Additional raw materials = 6,000 x $ 350 = $ 2,100,000 / year
- Additional labour costs =

Figure 11

FOM

**CORRECT EVALUATION OF INVESTMENTS**

giz

- Additional labour costs:

Machine A = 6,000 units x 8 min. / unit = 48,000 min.
= 800 h x $ 10 / h = $ 8,000

Machine B* = 6,000 units x 10 min. / unit = 60,000 min.
= 1,000 h x $ 10 / h = $ 10,000

Machine C = 6,000 units x 5 min. / unit = 30,000 min.
= 500 h x $ 10 / h = $ 5,000

Machine D = 6,000 units x 6 min. / unit = 36,000 min.
= 600 h x $ 10 / h = $ 6,000

Total additional labour costs = $ 29,000 / year

* old machine B

Figure 12

FOM

**CORRECT EVALUATION OF INVESTMENTS**

giz

Reactivation of old machine B if new B is still a constraint:

- Additional investment = $ 0
- Usable capacity increase = 6,000 units / year
- Sales increase = 6,000 x $ 500 = $ 3,000,000 / year
- Additional raw materials = 6,000 x $ 350 = $ 2,100,000 / year
- Additional labour costs = $ 29,000 / year
- Additional throughput per year = $ 871,000 / year

Figure 13

Now the investment in a new machine B combined with the reactivation of the old machine B will give us a total of $1,091,250 of additional throughput per year, reducing the payback period to a mere 0.46 years, which is less than 6 months.

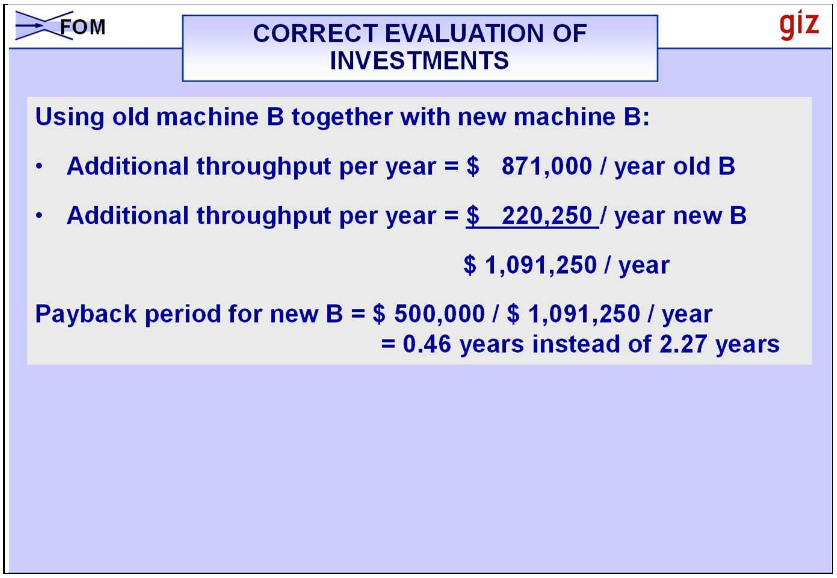

Figure 14

Since the total capacity of old B and new B amounts to 61,500 units/year, machine A is the new constraint. According to figure 10, we must focus our analysis on A and contemplate an investment there. Although the initial investment budget was limited to $500,000, the necessary investment sum of $80,000 for a new machine A will be available after 1 month of operating old and new B. The new machine A will have a total production capacity of 75,000 units/year to satisfy the demand of 45,000 units/year. Therefore only 7,500 units/year of additional capacity from A is required.

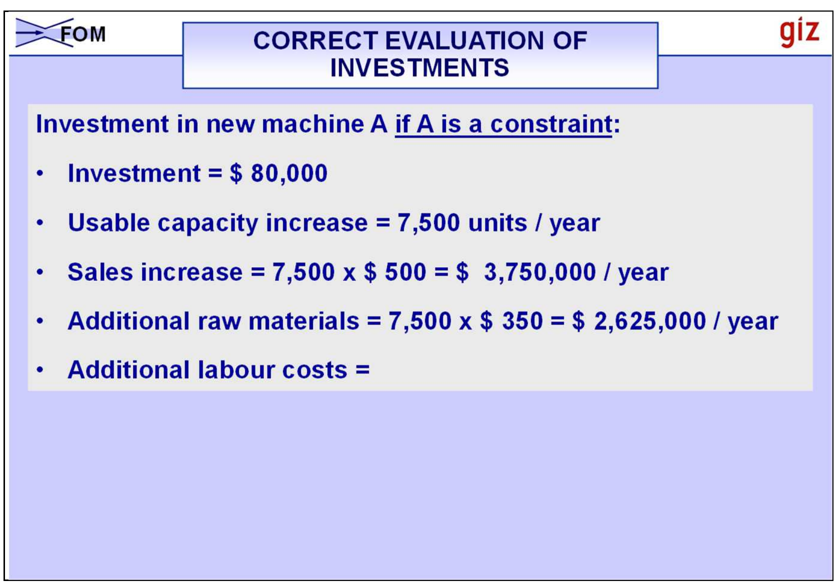

Figure 15

Again, in order to achieve the new production level, the working hours at machines old B, C, and D must be increased.

**CORRECT EVALUATION OF INVESTMENTS**

- **Additional labour costs:**

**Machine A = 75,000 units / year new capacity**
**<u>– 45,000 units</u> / year required capacity**
**= 30,000 units / year spare capacity**
**= 30,000 units x 4 min. / unit = 120,000 min.**
**= 2,000 h x $ 10 / h = $ 20,000 savings**

**Machine B = 7,500 units x 10 min. / unit = 75,000 min.**
**= 1,250 h x $ 10 / h = $ 12,500**

**Machine C = 7,500 units x 5 min. / unit = 37,500 min.**
**= 625 h x $ 10 / h = $ 6,250**

**Machine D = 7,500 units x 6 min. / unit = 45,000 min.**
**= 750 h x $ 10 / h = $ 7,500**

**Total additional labour costs = $ 6,250 / year**

Figure 16

**CORRECT EVALUATION OF INVESTMENTS**

**Investment in new machine A <u>when A is a constraint</u>:**

- **Investment = $ 80,000**
- **Usable capacity increase = 7,500 units / year**
- **Sales increase = 7,500 x $ 500 = $ 3,750,000 / year**
- **Additional raw materials = 7,500 x $ 350 = $ 2,625,000 / year**
- **Additional labour costs = $ 6,250 / year**
- **Additional throughput per year = $ 1,118,750 / year**
- **Payback period = $ 80,000 / $ 1,118,750 / year = 0.072 years**

Figure 17

**CORRECT EVALUATION OF INVESTMENTS**

**Buying new machine B, using old machine B,**
**and buying new machine A:**

- **Additional throughput per year = $ 220,250 / year new B**
- **Additional throughput per year = $ 871,000 / year old B**
- **Additional throughput per year = $ <u>1,118,750</u> / year new A**

**$ 2,210,000 / year**

**Payback period* = $ 580,000 / $ 2,210,000 / year = 0.26 years**

* if sufficient investment resources are available

Figure 18

Following the above investment sequence based on FOM it becomes clear why the throughput perspective usually offers a much higher yield than the cost saving focus. This does not mean that we should not pursue cost saving opportunities at all – it means that we should always take a priority look at the opportunities to increase the business.

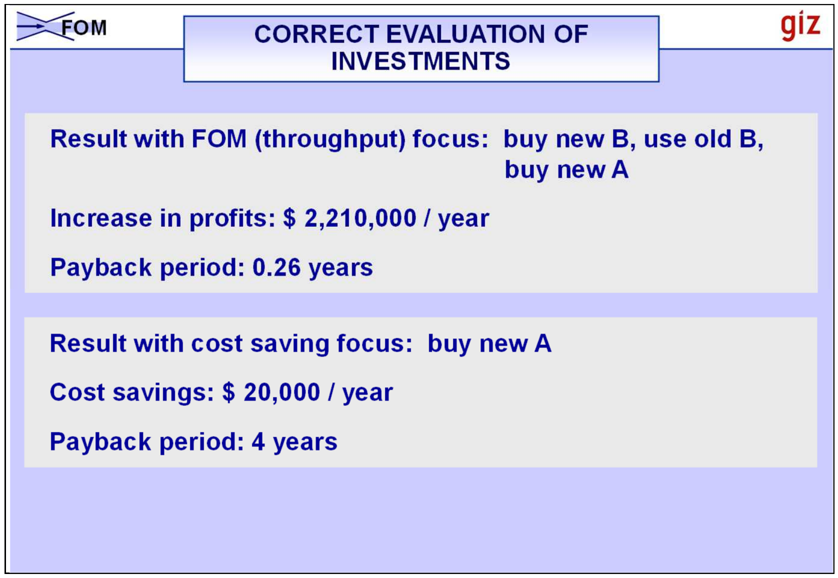


Figure 19

Due to the fact that the presently existing machine resources A, B, C, and D all have a higher available capacity than the current demand, there is no longer a constraint in the production area. The constraint has now shifted to the market.

In the event that the market demand for product P is limited by the price level, the company may now have the option of lowering the prices to create an additional demand and further increase its profits.

All of the above explains to some extent why companies may be on an exponential performance curve or just striving for survival.

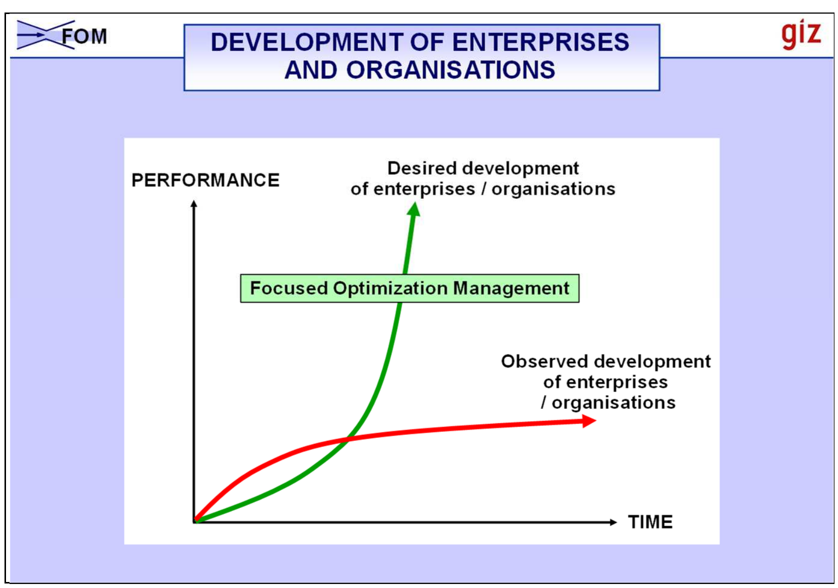


Figure 20

**Physical flow constraints vs. throughput constraints**

The above example may give the false impression that the resource with the least production capacity is always the constraint. However, according to the definition of throughput, it is not the flow of the physical products but the flow of the monetary value attached to the products that really matters. Therefore it is important to always look for the throughput constraints which may not necessarily coincide with the physical flow constraints as the following example will show.

If in the already given system of the preceding example another investment opportunity appears, a new analysis must be performed. In this case there is a proposal to replace the old machine C with a new machine C that will lower the material costs per unit from $350 to $280 by using less material and thus contributing to reduce the impact on the environment. The new machine will not increase the production efficiency / capacity.

FOM — INVESTMENT EVALUATION — giz

| Investment in new machine: | C | B |
|---|---|---|
| • Investment = | $ 150,000 | $ 500,000 |
| • Useful life = | 10 years | 10 years |
| • Efficiency increase = | 0% | 5% |
| • Actual production time = | 5 min. / unit | 10 min. / unit |
| • Future production time = | 5 min. / unit | ≈ 9.5 min. / unit |
| • Time savings = | 0 min. / unit | ≈ 0.5 min. / unit |
| • Production / year = | 30,000 units | 30,000 units |
| • Operating costs* = | $ 10 / hour | $ 10 / hour |

* direct labour expenses

Figure 16

FOM — INVESTMENT EVALUATION — giz

| Investment in new machine: | C | B |
|---|---|---|
| • Actual capacity / year = | 60,000 units | 30,000 units |
| • Actual production of P = | 30,000 units / year | |
| • Demand of product P = | 45,000 units / year | |
| • Available production time = | 5,000 h / year | |
| • Sales price of P = | $ 500 / unit | |
| • Raw material costs = | $ 280 / unit instead of $ 350 / unit | |
| • Available investment resources = | $ 500,000 | |

Figure 17

The new picture of the system shows the two constraints: the physical constraint at B and the throughput constraint at C. In order to identify the real constraint in this case, one must calculate the gross throughput (without operating costs) for B and C. According to the data in figure 17, the system's throughput margin with the old machine B is $500 – $350 = $150. This is multiplied by the number of units that can be produced (30,000 units / 5,000 hrs. = 6 units/h.), thus arriving at a gross throughput of $900/h. This must be compared with the case when the new machine C will operate with a throughput margin for the system of $220. Since the production rate of the physical constraint B still remains at 6 units/h., the potential gross throughput will amount to $1,320/h. which is much higher than $900/h. Therefore the old machine C is apparently limiting the throughput more than old B.

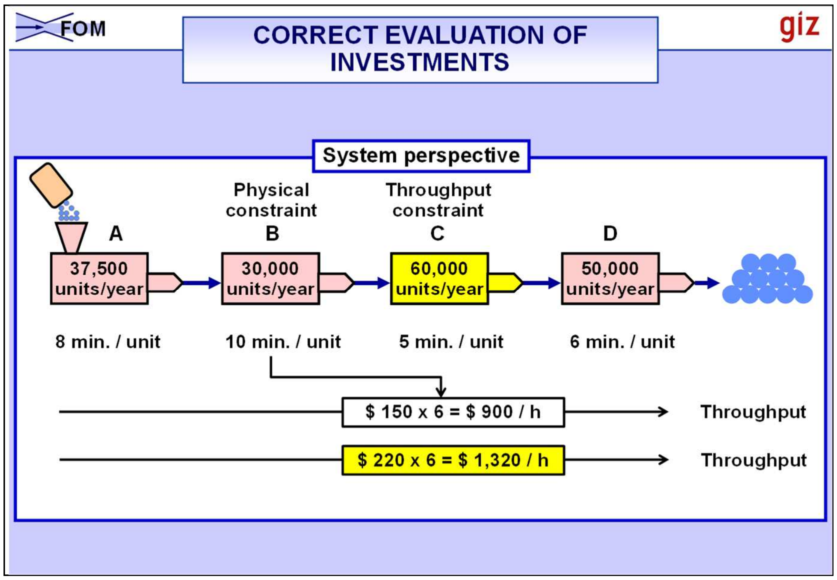


Figure 18

In order to come up with the optimal investment decision, we must now compare the alternatives of buying new C or buying new B, which we already did in figure 14.

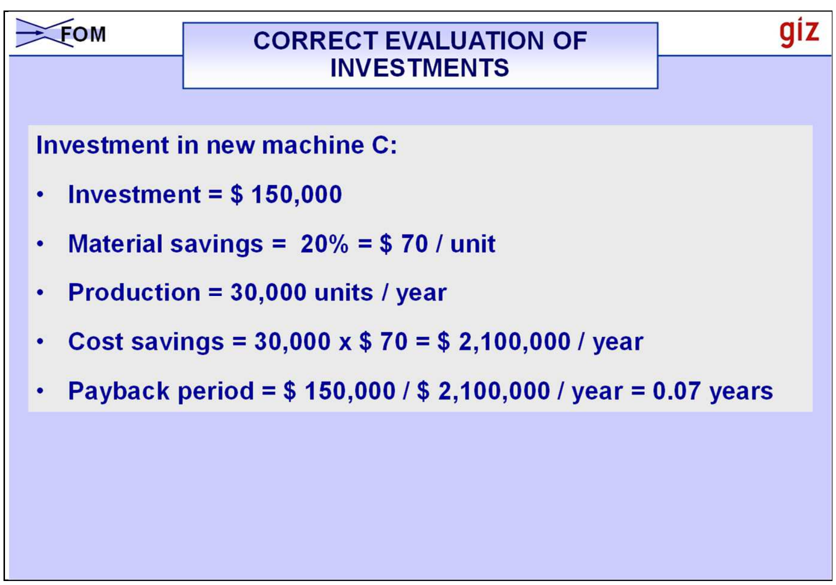


Figure 19

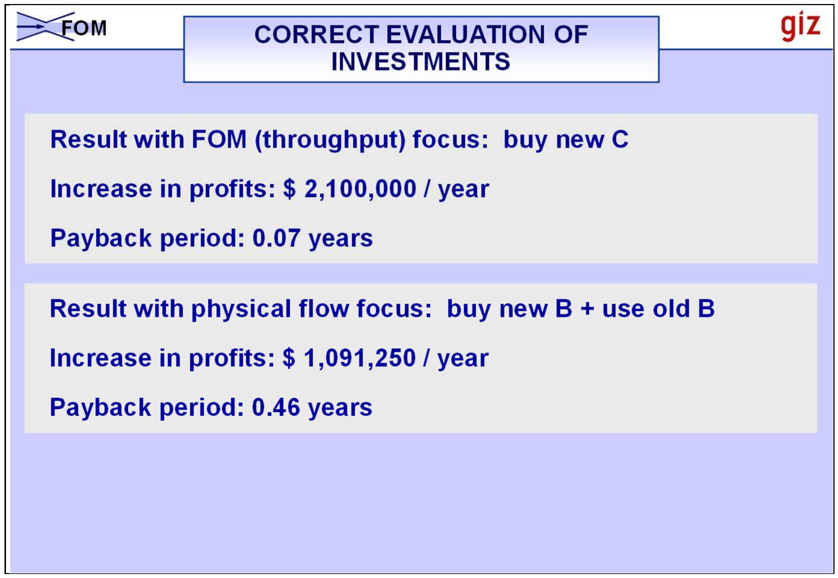


Figure 20

The comparison shows clearly that in this case the new machine C is by far the better investment.

Now the new investment sequence should be to buy new C, then buy new B and keep operating old B, and finally buy new A.

### Throughput vs. payback period as investment decision criteria

The following example will show, why contrary to conventional wisdom, investment decisions should be based on throughput results instead of payback periods.

In the present case we assume that the new machine C will bring down the material expenses by $25 to $325/unit.

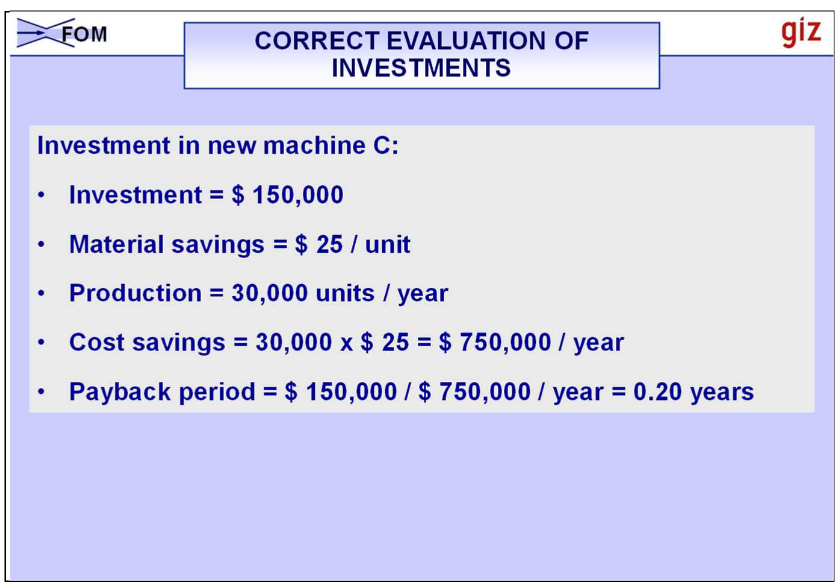


Figure 21

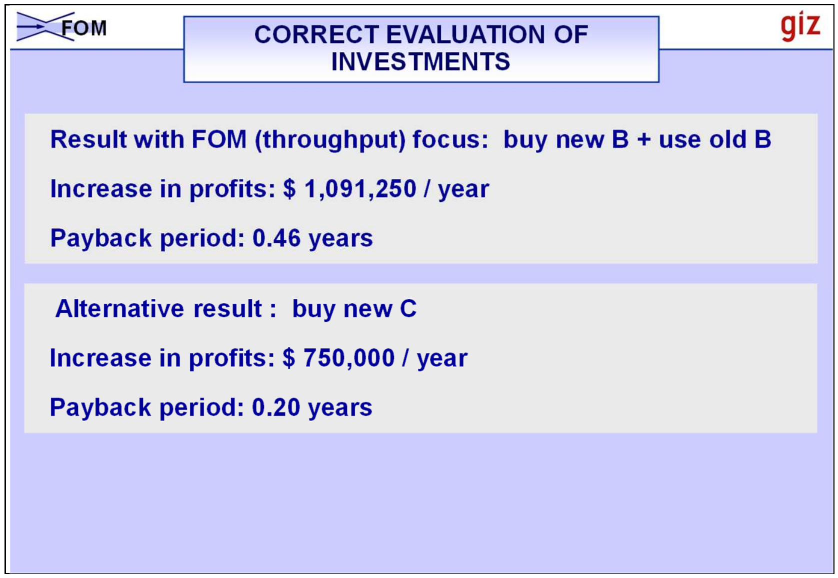


Figure 22

Judging by the payback period, C seems to be more advantageous than B. However, if we take a close look at the throughput, B shows a higher increase in profits.

Important conclusion:

Throughput and not the payback period is the correct measure to decide on investment opportunities.

It might be argued by someone that in the case of C the invested $150,000 will be recouped in less than 3 months and could be reinvested more quickly in other, profitable investments. Even the remaining $350,000 could be invested in a profitable way. If the $150,000 are not used to invest first in B, the company will forgo $218,250* – $150,000** = $68,250 of possible additional profits during the 0.20 years.

The question in this context is, if there can be more profitable investments outside of a throughput constraint. The answer is a clear no, because the system's performance always depends on the limiting effect of existing constraints.

* $1,091,250 x 0.2 years = $218,250

** $750,000 x 0.2 years = $150,000