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The Theory of Constraints as a Method of Results Optimization in Complex Organization

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Abstract

The paper presents the theory of constraints (TOC) as a method used to improve results in a complex, multiplants organization. In the article the assumptions of this method has been presented as well as iterative approach concerning how to launch it in practice. Main indicators for organizational effectiveness assessment have also been presented.
The maximization of production assets utilization is a key issue for competitive organization in the changing market conditions. An appropriate usage of the theory of constraints enables efficient allocation of financial assets among particular plants within a capital group. An application of a method has been presented based on throughput analyses and its influence to improve financial results of one plant organization and synergy effect in multiplants organization. The theory of constraints can be used in almost every kind of business sectors, among them are metal and foundry industries. It allows to be implemented in production organizations as well as in any other company's profiles. Everywhere the constraint has been defined there is a chance to achieve an improvement following the presented method. The examples have been taken from the casting plants which use continuous and mold casting technologies. The examples show that TOC approach can be successfully employed as the improvement tool of foundries' performances.

Keywords: Theory of constraints, Results optimization of production organization, Foundry performance

1. Introduction

Looking at the economic results of production companies with complex and multiplant structure they seem to be worse in comparison with the companies with single plant organization. It happens despite the fact that big corporates take lots of affords and initiatives to continuous improvements, fixed cost reduction and investments in new technologies. What is more, it also happens in spite of raw material dominance, better sales price, better productivity or higher innovation index.

The theory of constraints (TOC) can be used to explain the above observations. TOC as a method of optimization of the operation of complex companies. The practical purpose of the theory of constraints enables:

- focusing on the essential problem in the particular plant, business segment or organization,
- focusing all affords on the particular constraint and reducing expenditures on other elements which are not a bottleneck and finally reducing operating costs and capital expenditure,
- defining necessary indexes, based on which it is easy to detect whether the implemented change gives a positive or negative impact on results [1].

There are many examples of effective and successful implementations of the theory of constraints in accounting,

marketing, sales or purchasing, however most often it is used in production management [1, 2].

The aim of this paper is to present the effective method for operational management of single and multiplants foundries. The application of TOC in foundry industry was reported only in a few papers. Peng and Chen [3] developed a production scheduling model of the aluminum casting with equipment and process constraints, where TOC was used as an optimization strategy. Kyncl [4] solved a case study at Komercni Foundry (Czech Republic): five critical sources were found out by observing the production process and according to the accumulation of the work-in-process inventory. The author concluded that capacity of bottlenecks that are influenced by human work can be improved without significant problems. More recently, Mpanza, and Nyembwe [5] studied a case study at a South African foundry company - the company's production processes were observed over a period of ten months. The production constraints were then identified and some projects to assist improve operations were proposed. The authors discussed three of these projects: labor efficiency, plant capacity and lead time.

2. Comparison of single and multiplants models

Production companies can be divided into single plant organizations and multiplants organizations with complex structure. Companies from casting, metallurgical or machine industries are the examples of such a division. The purpose of establishing the multiplants, complex organizations is to increase production capacities and mainly to improve economical results in a given company. The creation of a new multiplants structure can be done simultaneously with the modernization of technological processes and sometimes with a replacement of exhausted fixed assets. All these changes ought to contribute towards better technical, economical and organizational effects. The main characteristics of analyzed models have been presented in Table 1.

Table 1.
The comparison of single and multiplants organizations.

No	Single plants	Multi plants
1.	One geographical location	Many locations
2.	Simple structure	Distributed structure
3.	High utilization of production capacity	Not full utilization of production capacity
4.	The necessity to execute of all orders	The opportunity to distinguish orders between the most efficient plants
5.	The increase of sales abroad in case of the weak economic situation	The small possibility to increase sales by the price decrease on the other markets
6.	The weak total economic situation influences the market less harmful	The weak total economic situation equals usually a decrease of production plans and production capacity in all plants
7.		Synergy effect

Source: own elaboration.

As far as optimization of economic results is concerned, the synergy effect is a big advantage in multi plants organization. However, the global organization can increase the added value due to the scale of its installation, product portfolio or multiplicity of its locations only if the central steering is implemented (central planning of sales, purchasing, production, raw materials allocation etc.). Such an approach leads to limitation or even elimination of the internal competition and the price or sales fights on the same markets. What is more, the purchase of raw materials and other materials needed in production processes can be carried on globally for the better price. The key aspect of this approach is the production central steering and production orders allocation between plants. The goal is to maximize results, minimize nonproductive operation times and costs [6, 7].

From traditional point of view, the company assumes to achieve small improvements in many areas of its activities to finally achieve an improvement of the whole system (organization). From that perspective, production teams very often are to reduce fixed costs and maintenance expenditures based on benchmarking among different plants. As a consequence, there are risks of reliability deterioration and reduction of production volumes in a particular plant. In the macro scale, every plant wants to have the lowest possible reported cost. It will cause internal competition within the group for the cheapest raw materials or/ and for the more profitable orders at a given moment. The situation described above can be observed in many complex companies with multiplants structures. It mainly happens, because:

- effectiveness indicators drive local actions to optimize results locally,
- lack of knowledge whether local change brings the improvements of results globally,
- conviction that small improvements can be done in every area,
- lack of a proper business model allowing to optimize the whole system.

Of course, to achieve an improvement the change is needed. However, not every change is reasonable, e.g.:

- why increase the sales of a product X if it has lower EBITDA than product Y?

- why launch the new and cheaper product on the market and reduce the sales of the other with high added value which is being produced by the other plant within the group?
- why locate the production of complex products in the dedicated plant if transportation costs from local plants are much lower?

In the consequence, there are three open questions:

- is the implemented change a real improvement?
- How to motive all employees (regardless of hierarchy) to realize goals of the whole organization?
- **How to optimize multiplants organization as a whole?**

One of the method which enables to answer these questions is the theory of constrains. It is characterized by methodical procedure how to optimize results in a complex organization.

3. The principles of theory of constrains

The theory of constrains is inextricably linked to Eliyahu Goldratt who is known as an author of the theory of constrains [1] and its applications in almost every area of company's activities.

According to the theory of constraints the complexity of the system is not a drawback but an opportunity. The opportunity to improve in the relatively easy way the whole organization through the influence of small number of its elements.

The key point is to clearly identify elements which guide the whole system together with a definition of causal links between them. These relations define the material flow, information flow etc. Keeping them as a background, potential constraints are set out. Constraints have to be considered widely because they can affect both internal and external relations in the organization.

Each organization is a system which is oriented on goals and its effectiveness is limited via the weakest link ("systemic constraint", "bottleneck"). The constraint arises from the hierarchy of elements which form the complex structure of the system.

The significant improvement of the organization can be achieved only through the flow improvement of the weakest link. The theory of constraints method consists of five steps (Figure 1).

The **first** step is an identification of a strategic constraint. It is a key step which determines future activities of organization. Apart from this, it is extremely important to distinguish all components of a constraint and determine opportunities and potential investments (in next steps).

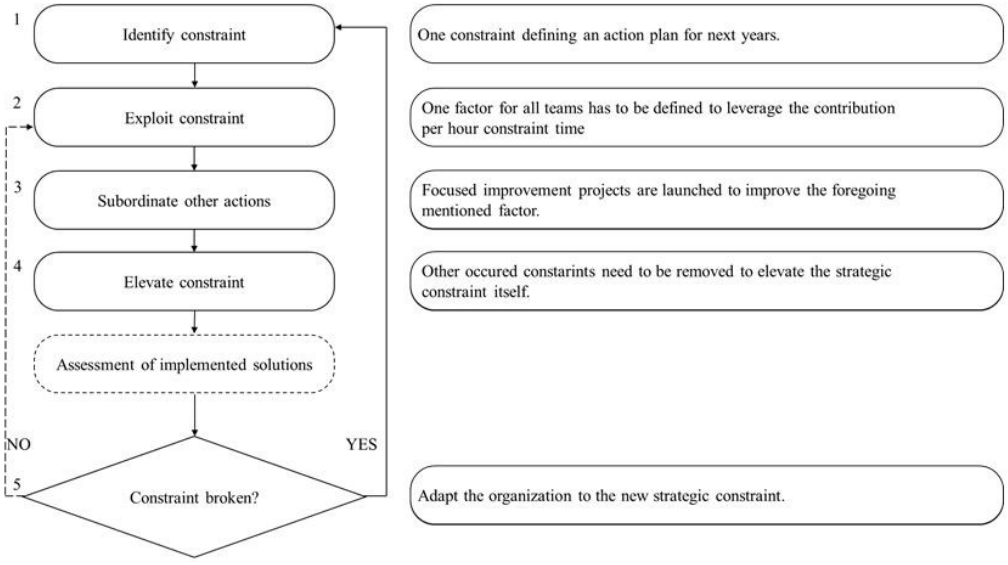

Fig. 1. Five steps of theory of constraints. Source: own elaboration based on ArcelorMittal FCE CTO

In the **second** step, it is necessary to decide how to interpret a strategic constraint. It is crucial to define a factor as a measurement, which has to be used by all teams within organization to maximize the leverage effect between contribution and working time of the installation which is a bottleneck.

The **third** step is a subordination of all activities for a strategic constraint. Short and long term projects are launched in an organization which are to improve the factor defined in the second step.

In the **fourth** step the efficiency of the element which is a constraint has to be reinforced. It usually requires to bear the costs.

In this step all other constraints which are not strategic have to be eliminated.

In the first and fourth steps strategic investments decisions are taken.

After elimination of strategic constraint, there is a risk of inaction in an organization. That is why in the **fifth** step it is necessary to return to the first step to consider whether the new strategic constraint occurred or not.

According to the general theory of systems each organization operates in a certain business environment. Thus, the bottleneck identification and its elimination should base on the markets analyses, supply and demand analyses, and competition analyses.

An increase or decrease of system capacity should base on them (without any consequences of market loss or damage) [8, 9, 10].

4. Result measurement in theory of constraints

The theory of constraints is based on two fundamental rules:

1. The first rule encompasses the identification of the weakest link and evaluation of the best activities to eliminate it. The throughput has been changed and it is adjusted to workflows in an organizational structure.
2. The second rule encompasses the measurement what is the impact of the implemented actions on:
   - T, Throughput = money generated through sales = difference between income and variable costs (mainly of raw materials purchased in the same period) = sales volume × contribution margin = sales volume × (unit price – unit variable costs)
   - I, Inventory = money tied up in the system under the form of inventory, equipment; it includes: real estate, equipment, raw materials, work in progress, final products, patents, trademarks, etc.
   - OE, Operational Expenses = all money spent within the system to turn inventory into throughput = all fixed costs = salaries, repair and maintenance, overheads, etc.

Appropriately to the above mentioned rules, it is important to follow the procedure shown on Figure 2.

The next disputable issue is the way how to measure the effectiveness of implemented changes. Currently, EBITDA/ton is commonly used as an indicator of production line effectiveness. According to the theory of constraints it is not the best indicator for the whole system, because:

- this is not an universal indicator – sometimes it is a good decision to sale orders with negative EBITDA/ton,
- it is not measurable on the production floor – depends on future occupancy which is unknown in advance.

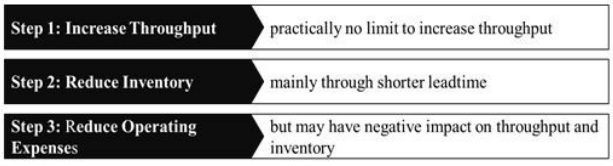

Fig. 2. The hierarchy of steps in the theory of constraints. Source: own elaboration based on ArcelorMittal FCE CTO

The theory of constraints says that the throughput should be a keystone of effectiveness measurement due to its advantages as follows:

- it is measurable on production floor,
- it depends on sales,
- it is not related to operation costs,
- it is universal.

Sale of products with positive true contribution margin (TCM) gives profit for the company. The EBITDA for a particular order can be negative (due to unexpected losses or high fixed costs). The salesman is however sure that she/he did right if the sales concerned products with the highest possible TCM [11, 12]. There are some examples of managerial decisions and activities regarding above mentioned factors:

- Sales directors can use throughput to concentrate sales activities based on TCM ranking,
- Plant directors can check (measure) net profit via throughput measurement on production lines which are bottlenecks and encompassing daily operating expenses (1/365 of the budget for operating expenses),
- Executive directors can improve throughput via increasing materials/products flow on bottlenecks and via decreasing variable costs.
- Financial directors can monitor throughput in respective periods to check whether managerial profits are actually taken into consideration in incomes.

5. An example of throughput as a tool of performances improvement

A plant mass-produces semi products for further processing in rolling mills for automotive and machinery industries applications on the local market. Fixed costs equal 40 million PLN. Sales is on the level on 250 thousand pieces. The true contribution margin is equal to 200 PLN/unit.

Profitability curve oscillates about 200 thousand units, therefore the throughput is equal to 50 million PLN. The EBITDA profit is 10 million PLN.

Suppose that there are three possible scenarios:

Scenario 1

1. An increase of true contribution margin up to 225 PLN/unit due to sales price increase on the domestic market.
2. As a consequence, the sales volume decreases by 10%.

Scenario 2

1. Sales increase on a domestic market by 10% (275 000 units).
2. Sales price decreases by 10 PLN.

Scenario 3

1. To maintain fixed price on the domestic market.
2. Utilization of additional production capacity (15%).
3. To generate 15% additional sales on export market at available production capacity and true contribution margin at 120 PLN (-40 PLN). Acknowledgements should be placed before references.

The analyses of the effects based on respective scenarios look as follows:

- According to the scenario 1, an increase of sales caused an increase of throughput to 50 625 000 PLN (despite the market loos). The EBITDA profit increased by 625 000 PLN (+6.25%).
- According to scenario 2, a decrease of sales prices caused an increase of domestic market share and an increase of throughput to 52 250 000 PLN at the same time. The EBITDA profit increased by 2 250 000 PLN (+ 22.5%).
- According to scenario 3, the utilization of additional production capacity and sales increase on external markets

at the same time caused an increase of throughput to the level of 54 500 000 PLN. The key point is to keep the fixed sales prices on the local market (not to ruin the market). Instead, it is a very interesting phenomenon, that in spite of the true contribution margin decrease for exported products, the EBITDA profit stands at 14 500 000 PLN (+45.0%).

6. An example of the plants synergies

The tendency to create the multiplants organizations occurs also in foundry and steel industries. Form practical point of view it is a merger of the plants from various geographic locations and their modernizations at the same time.

For the companies with multiplants organizational structure which has many geographical locations, a synergy effect is a key aspect. An example below shows how the throughput T together with well working central planning system can cause the growth of incomes in the whole organization.

Plants A and B are parts of European consortium producing ingots via continuous casting or mold casting methods. The typical ingots differ with respect to grade, length and width.

There are two main but different bottlenecks in both plants. The simulation below regards two orders from the clients with a very similar production profile. The true contribution margin remains at 200 PLN/ton.

The order for Plant A concerns the product with 1 meter width and 7 meters length.

The order for Plant B concerns the product with 1.25 meter width and 12 meters length.

Plant A

- The bottleneck occurs on a production line for finished goods.
- The order concerns the product which is 1 meter width.
- There is the constraint in terms of semi product length because of the client restrictions regarding a final product weight.
- The capacity of final products production line stands at 2 t/ min.
- The throughput limitation for Plant A remains at 400 PLN/min.

Plant B

- The bottleneck occurs on a production line for semi products.
- The order concerns the product with 1.25 meter length.
- There is no client restrictions regarding final product length.
- The capacity of semi products production line stands at 5.2 t/ min.
- The throughput limitation for Plant B remains at 1040 PLN/min.

On the assumption that, the allocation of these two orders has been changed, namely the order for Plant A is given to Plant B and vice-versa.

a) Plant A will optimize its throughput by elimination of a final product length restriction.

b) Plant B thanks to technical capabilities of its semi product production line, namely a possibility to produce semi product with 2 meters width will optimize throughput by the production of double width semi products. Then they could be cut according to the technical requirements placed in the order.

If such a solution is implemented, then the capacity of production line in Plant A will change and the length of the product is relevant at the same time. The change will occur also in Plant B which is able to produce semi products with maximum width. As a consequence, the final throughput will change and amounts 1 000 PLN/min for Plant A and 1 640 PLN/min for Plant B, respectively. The results of TCO analysis are presented in Table 2.

Table 2.
Total throughput for Plants A and B after the change of the orders.

	Plant A		**Plant B**	
Order (200zł/t)	Capacity/min.	TCM PLN/min	Capacity/ min.	TCM PLN/min.
1000 mm (width) x 7m (length)			8.2	1640
1250 mm (width) x 12m (length)	5.0	1000		
After Change		**TCM (A+B) = 2640 PLN/min.**		

Source: own elaboration

7. Conclusions

In this paper, some aspects of the theory of constraints were presented. If TOC is well implemented it can bring big economic results in the organization. Of course some key rules need to be respected. It is extremely important to identify where the strategic constraint is for every level of the organization. However, the local/tactical constraints cannot be the same as previously identified strategic ones. What is more, it is crucial to use Throughput, Inventory and Operating Expenses as the indicators to measure financial results in the organization. It makes the measurement somehow independent of e.g. raw material prices.

Analyzing the organizations with complex, multiplants structures, it is important to strive to maximize the diversities of them. They should not have the same strategic constraints, the same mission or the same sales markets. The organization as a whole wins the possibilities to allocate the orders along the plants maximizing flows on defined bottlenecks. Thanks to this synergy effect can be achieved between plants. The orders can be placed in a correct (economic) way and internal competition can be eliminated.

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