

Using theory of constraints for reaching optimal product mix: An application in the furniture sector

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Abstract

With the globalization, intense competition and technological advances, the inadequacy of the traditional management and cost accounting methods that meet the needs of firms and achieve their goals has led to the development of new methods, such as theory of constraints. Theory of constraints, developed by Goldratt in 1980s, is defined as effectively managing the constraints that prevent firms from achieving their goals. In the theory of constraints, it is focused on increased restricted contribution margin, reducing inventories and operating expenses. Thus, profitability can be improved by directed enterprise resources efficiently.

The purpose of the study is to provide effectively managed constraints by defining constraints that prevent their targets and thus to increase the profitability of firms. For this purpose, theory of constraints practice was carried out in a furniture firm which operates in the Mediterranean Region. As a result, it is found that, there are capacity constraints in the firm and the profitability will increase 42% after the elimination of this constraint.

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1. Introduction

Traditional methods were not sufficient neither for cost accounting nor management accounting in the globally competing markets (Büyükyılmaz & Gürkan, 2009: 178). Such a business environment forces firms to use their resources more efficiently for reaching their main objectives which are increasing profitability and value. Firms

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should use modern management and cost accounting techniques as theory of constraints in order to reach these goals.

For 30 years, theory of constraints has been widely used by many public or private companies which operates in production, logistics, distribution, project management, R&D, marketing etc. (Ronen, 2005: 1–2). The Theory of Constraints is widely analyzed in the scientific sources in different countries. In Lithuania Čiegis and Jasinskas (2006), Jaasinavičius et al. (2006), Pukėnaitė (2006), Sarapinas and Sūdžius (2009) analysed the theory of constraints in different aspects. Firms which have used theory of constraints and the positive change in their performance indicators are summarized below (Goldratt, 2004: 2).

- Avery Dennison: At the end of 18 months of application process, 32% decrease in the waste materials, 17–25% increase in market share, 23% increase in net sales, 47% increase in customer satisfaction, 80% increase in filling order rate, 50% increase in the sales of new products.
- TBS Furniture: Filling order rate decreased from 6–8 weeks to 1 week while sales increased 80%, delivery speed increased 97%, operating costs decreased 40% and stocks decreased £2 million. And capital turnover reached to £17 million from £13 million.
- Ford Motor Company: Filling order rate decreased from 10.6 days to 2.2 days while delivery time and quality mistakes decreased 60–70% and 50% respectively. Meanwhile, customer satisfaction, investment efficiency and in time delivery increased 75%, 20% and 38% respectively.
- Motorola: Production time decreased 20% while throughput (outcome) of this process increased 150%. Production capacity extension possibility increased by using latest technology.
- Pharmacia: Order delivery time decreased more than 60% and packaging rate increased from 20% to 50%. Delivering the orders in time increased over 90%.
- Rockwell International: Costs decreased 25%, disorders in the production process decreased 31% and time spent for controlling the outcomes decreased 44%.
- Boeing: Order delivery time decreased 75%, stocks decreased 60% while throughput (outcome) increased 50%. Just in time delivery rate almost reached 100%.

The other international companies that apply theory of constraints are; ABB Corporation, AT&T, Bell Laboratories, Baxter, Delco Products, Delta Airlines, General Motors, Harris Semiconductor, Hewlett Packard Puerto Rico, Intel International, IPL, National Semiconductor, Naval Aviation Depot, Pratt & Whitney Government Engines, Procter & Gamble, Samsonite S.A., United States Air Force, United States Coast Guard (İlhan, 2014: 8).

2. Theory of constraints

At first theory of constraints was identified as managing the difficulties which prevent the reaching firms to their goals. But later, it was improved by Goldratt and that's how it could be also used in management and cost accounting (Ronen, 2005: 1–2).

According to Goldratt, activities in the firm resemble to a chain and every chain has a weak link which is defined as constraint according to the theory of constraints. Since the strength of the chain depends on the weakest link, first the weakest link should get strengthened. Strengthening the weakest link means eliminating the constraint and leads to improvement of the whole system (Büyükyılmaz & Gürkan, 2009: 181). According to the theory, there is at least one constraint in any firms that prevents the management to reach its goals. Theory of constraints basically claims that the capacity of a firm is limited with the constraints in the production process. Therefore, it is necessary to define and eliminate the constraints in order to increase the firm capacity. According to theory of constraints eliminating a constraint leads to the occurrence of another constraint and this new constraint also should be eliminated. Hence, theory of constraints leads firms to focus on constant improvement process (Yüksel, 2011: 3624). Main assumptions of theory of constraints are summarized below (Huang, 1999: 21–27; Kaygusuz, 2006: 175):

- *Main purpose of firms is gaining profit:* If a firm thought as a chain then this chain as strong as the weakest link. From this point of view, weakest link should be found and strengthened. In the full costing method, costs are charged equally to the links and weakest link also get the same share as the strong links. So, traditional

cost accounting methods like full costing method does not focus on increasing the share of outcome from weakest share while theory of constraints does.

- *Direct labor cost is regarded as running expenses:* In theory, all expenses are regarded as running expenses except direct raw materials and supplies expenses. The difference between sales and except direct raw materials and supplies expenses is defined as limited cash flow. Net profit or loss is the difference between limited cash flow and running expenses. In theory, profitability is calculated with sales price, sales amount and direct raw materials and supplies expenses. Besides that, direct labor expenses and manufacturing overhead costs is defined fixed cost.
- *There is at least one constraint for each product:* There are external and internal factors that prevent firms to gain profit. It is necessary to identify which constraints have effects in the short term (bottleneck) and long term (constraint). It is easy to identify capacity constraints since they generally occur at the production processes. It is difficult to identify and control the constraints which is unexpected or affects the firm externally.
- *Planning the product flow in the chain is difficult:* This assumption follows up the last one and suggests that priorities should be defined and all should be planned accordingly in case of any constraints and unexpected circumstances. While planning, constraints should be defined and change in products and product mix should be taken in consideration.

The application of theory of constraints consists of five steps (Büyükyılmaz & Gürkan, 2009: 185; İlhan, 2014: 4; Kaygusuz, 2011: 176):

- Identifying the constraints,
- Exploiting the constraints effectively,
- Subordinating every related decision to the constraints,
- Elevating the constraints,
- Starting from first step again when the constraint elevated.

Constraints should be classified in order to be managed (Büyükyılmaz & Gürkan, 2009: 181). Constraints can be classified as market constraint, capacity constraint, politic constraint, raw material constraint, logistics constraint, behavioral constraint and administrative constraint. These constraints are briefly explained below:

Market constraints: This is an external constraint which has many reasons but generally aroused from administrative politics. The strategy for eliminating the market constraint is trying to increase the demand for the products. Increasing the demand for products can be obtained by gaining competitive advantage which means improving the production process. So that, throughput (outcome) will increase while stocks and running expenses decreasing (İlhan, 2014: 12).

Capacity constraints: It occurs as a result of insufficiency of specific resource to meet the demand of the market. Capacity constraint is a factor that breaks the production flow and cause decline in the sales revenue as a result of failing to meet market demand. Capacity constraints can be bottleneck resource or not (İlhan, 2014: 12).

Politic constraints: It generally occurs at the marketing, accounting and finance departments. It is hard to identify and eliminate compared to physical constraints but once it is accomplished, it contributes more to the firms (İlhan, 2014: 14).

Raw material constraint: This constraint occurs as a result of raw material shortage in the production process (Tiryakigil, 2011: 63). In order to overcome raw material constraints whether new suppliers should be searched or the amount paid to the suppliers should be raised (İlhan, 2014: 15).

Logistics constraints: The reason of this constraint may be the planning or control system of the firm. Delays in the supplies, under supply and not sending the raw materials to the production can be given as an example to these constraints which prevent firms to increase their profit (Kaygusuz, 2005: 139).

Behavioral constraints: These are not the main reason of the problems in the firm but it is difficult to eliminate them. These constraints are obstacles for enhancing the production process (İlhan, 2014: 16).

Administrative constraints: It occurs as a result of the negative decisions of the managers and it is difficult to eliminate them. In order to eliminate, firms should be open to the innovations (Tiryakigil, 2011: 63).

Performance measures developed according to the theory of constraints then divided as financial measures and activity measures. Financial measures consist of net profit, return on investment and cash flows while activity measures consist of throughput (outcome), stock and running expenses (Lockamy & Spencer, 1998: 2049; Ünal, Tanuş, & Küçüksavaş, 2005: 434).

Throughput (Outcome); is found by subtracting raw material costs from the selling price of the product. Contribution margin is found by subtracting all the variable costs (direct raw materials and supplies expenses, direct labor expenses, variable part of the overhead expenses) from the selling price although throughput resembles to contribution margin. Throughput is found by subtracting direct raw materials and supplies expenses from selling price since only variable cost is direct raw materials and supplies expenses in the theory of constraints (Louderback & Patterson, 1996: 190). And the product which reaches the final consumer by passing all the production process is not called as output but stock. Briefly output or throughput is a measure which is found by subtracting raw materials and supplies expenses from the selling price of the product (Tiryakigil, 2011: 70).

Stock; is defined as the money invested in the product which the firm is going to sell and on the contrary to the traditional methods it is evaluated as raw material cost (Lockamy & Spencer, 1998: 2050). The definition of stock according to the theory of constraints is the total of production cost and labor costs (Tiryakigil, 2011: 70).

Running expenses; is defined as all the expenses that were made for turning stocks in the system into throughput. Running expenses include all the production costs except raw material costs (Lockamy & Spencer, 1998: 2050).

When a firm comes across with a bottleneck, the department or section should be empowered according to the type of the bottleneck. If the department which bottleneck occurred stays weak then it can be interpreted as this department does not function well. So by empowering the department the bottlenecks occurred during process will no longer exist and that's how firms can reach profit which is one of their basic goals (Büyükyılmaz & Gürkan, 2009: 184).

Firms should use their resources efficiently in order to reach their main goals. Beside that one of the factors which affect the profitability of a firm is cost and cost is used for calculating the amount of money spent for used resources. Thus, costs should be managed efficiently for making the profit sustainable. In this regard, it can be said that main purpose of the today's firms is revised as increasing profitability by reducing costs. But reaching these goals is not always possible due to the bottlenecks in the firms (Kaygusuz, 2006: 172).

Costs is classified as variable, fixed and mixed according to traditional cost accounting methods. But variability of costs is defined by sales volume not production volume in the theory of constraints, so the costs which change according to the volume like direct raw materials and supplies expenses, energy expenses and distribution costs are regarded as variable costs. In the traditional methods, variable costs has effect on the decisions which will be taken while fixed costs are regarded as sunk cost if they are not affected by the decisions. But in the theory of constraints, alternatives should be chosen by their distribution to the contribution margin. Besides that, all the expenses except the ones changes according to the sales defined as running expenses in the theory of constraints (Kaygusuz, 2011: 178).

Most important point that separate Goldratt from traditional cost accounting methods is that defining earnings as money entry to the system, stock as money in the system, running expenses as the money getting out of the system. In order to increase the profitability goal, it is important to increase contribution rate while decreasing stocks and running expenses. But Goldratt claims that profit can be increased by firstly increasing contribution rate, secondly decreasing the stocks and finally decreasing running expenses. Because, the benefit gained by decreasing the costs is limited while the benefit gained by increasing the sales is unlimited. Shortly, the main principle according to theory of constraints is to increase the contribution rate and decrease the stocks and running expenses (İlhan, 2014: 21).

Goldratt claims that cost calculating methods should be changed and managers should focus on managing the bottlenecks instead of calculating the product costs (Kaygusuz, 2006: 175). The costs which calculated according to the production volume do not reflect the real situation of the firm according to the theory. So, a financial performance estimate made according to the theory. Performance is estimated according to the relation between sales price, sales volume and variable cost which is defined as raw materials and supplies expenses. Firm should increase sales for increasing the profit, and bottlenecks should be defined then abolished for increasing the sales (Kaygusuz, 2005: 134).

Table 1
Theoretical capacity and expense centers of dining table, TV bench and coffee table.

| Expense center | Capacity |
|-----------------|------------------|
| Cutting | 11.520 min/month |
| Edge banding | 11.520 min/month |
| Montage | 11.520 min/month |
| Quality control | 11.520 min/month |

Focus point of the theory is decreasing stocks and the running expenses while increasing the contribution rate. According to the theory, these three criteria are enough for closing the gap between net profit and return on investment (İlhan, 2014: 22).

Defining and abolishing bottlenecks will improve the production process and help firm to gain competitive advantage by responding customer demands in time. Besides that, decreasing the unnecessary work in process inventory will lead to decrease in costs and increase in profitability (Ünal, Demircioğlu, & Küçükşavaş, 2006: 331).

3. Application of theory of constraints in the furniture sector

3.1. Introducing the firm

Selected firm¹ was established in 2003 and it makes mass production generally at Mediterranean region of Turkey at furniture sector. Product quality of the firm is high and firm works 24 h. The firm operates on 7200 m² land and in 5000 m² indoor space. And in the production fully integrated devices are used.

In the research, only the products, which are produced from the same raw material, like dining table, TV bench and coffee table are used. These products are not only produced from same raw materials but also they go through the same production processes. The products with these specialties are chosen on purpose because reaching the highest profitability is aimed by deciding the order of product production process according to theory of constraints.

Sequence of production processes are cutting, edge banding, montage and quality control. Totally nine people works at the firm and three of them at the cutting department, two of them at the edge banding department, three of them montage at the department and one of them at the quality control department. Workers work 6 days in a week, 8 h in a day and their wage for 1 month is 1500 TL (Turkish Lira which is the currency in Turkey).

As it is shown at Table 1, theoretical capacity of the firm at each expense center is 11,520 min/month ($8 \text{ h} \times 60 \text{ min} = 480 \text{ min/day}$; $24 \text{ day} \times 480$).

Production processes of the firm are shown at Fig. 1 below.

Table 2 shows the unit price and monthly demand of dining table, TV bench and coffee table. As it can also be seen from Table 2 unit price of dining table, TV bench and coffee table are 400 TL, 430 TL and 130 TL respectively while monthly demand is 240, 200 and 440 units.

Same raw material and supplies are used for all three products at the firm. In Table 3, the material used for producing dining table, TV bench and coffee table are shown. According to that, half panel of MDF, 22 m band (5 cm) and 40 pieces of minifix are used for producing one dining table. For producing one TV bench half of the MDF panel, 15 m band (5 cm) and 35 pieces of minifix are used. And quarter of MDF panel, 6 m band (5 cm) and 18 pieces of minifix are used for producing coffee table. Cost of raw materials are 150 TL for one panel of MDF, 2 TL for 1 m of band and 0.50 TL for one piece of minifix.

Unit costs of all three products to the firm were calculated according to theory of constraints can be seen in Table 4. According to that dining table costs 204 TL which consists of 139 TL direct raw materials and supplies and 65 TL running expenses, TV bench costs 198,785 TL which consists of 120 TL direct raw materials and

¹ Financial data are only used with the permission of the firm. But the name of the firm is hidden because it may lead some competition disadvantages for the firm in the future.

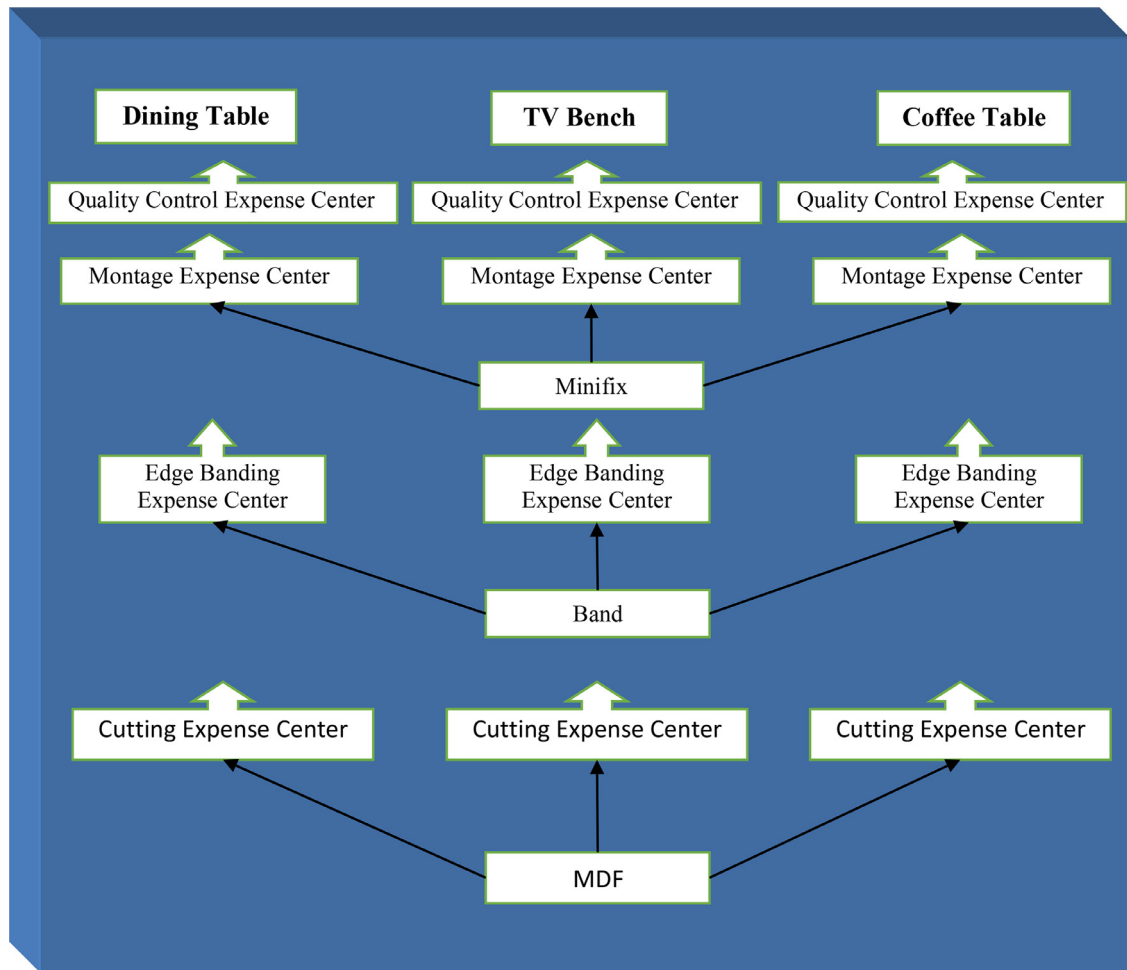


Fig. 1. Production process of dining table, TV bench and coffee table.

Table 2
Sales price and monthly demand of the products.

| | Products | | |
|--------------------|--------------|----------|--------------|
| | Dining table | TV bench | Coffee table |
| Sales price (unit) | 400 TL | 430 TL | 130 TL |
| Demand (unit) | 240 unit | 200 unit | 440 unit |

supplies and 78,785 TL running expenses and coffee table costs 87,25 TL which direct raw materials and supplies and 65 TL running expenses.

According to the theory of constraints all costs except direct raw materials and supplies are considered as running expenses. Starting from this point of view, direct labor cost is charged to products equally as it can be seen from Table 4. Direct raw material and supplies expenses of the products are estimated by retrieving data about necessary materials and their price for 1 unit from Table 3. Direct labor cost is charged to the products according to the production time.

Running expenses are considered as variable and fixed in the theory of constraints. Total running expenses of the firm is 113.568 TL and it is charged to the products according to montage time. When it is considered that firm produces 880 products, then running expenses (113,568/880) for one product is found as equal to 129.055

Table 3
Used direct raw material and supplies in products.

| | Products | | |
|---|--------------|----------|--------------|
| | Dining table | TV bench | Coffee table |
| Direct raw material and supplies (unit) | | | |
| MDF (panel) | ½ P. | ½ P. | ¼ P. |
| Band (m) | 22 | 15 | 6 |
| Outsourced item (Minifix-piece.) | 40 | 35 | 18 |

Table 4
Running expenses and unit cost of direct raw materials and supplies of products.

| | Products | | |
|--|--------------|------------|--------------|
| | Dining table | TV bench | Coffee table |
| Direct raw materials and supplies (unit) | 139 TL | 120 TL | 55,5 TL |
| MDF (panel) | 75 TL | 75 TL | 37,50 TL |
| Band (m) | 44 TL | 30 TL | 12 TL |
| Outsourced item (Minifix-piece.) | 20 TL | 15 TL | 6 TL |
| Running expenses | 65,00 TL | 78,785 TL | 31,75 TL |
| Direct labor cost (unit) | 17,26 TL | 20,71 TL | 8,52 TL |
| Variable running expenses (unit) | 19,10 TL | 23,230 TL | 9,292 TL |
| Fixed running expense (Br.) | 28,65 TL | 34,845 TL | 13,938 TL |
| Total production cost | 204 TL | 198,785 TL | 87,25 TL |

Table 5
Production time of the products according to production processes.

| | Ürünler | | |
|----------------------------|--------------|----------|--------------|
| | Dining table | TV bench | Coffee table |
| Cutting (min/unit) | 15 | 20 | 5 |
| Edge banding (min/unit) | 10 | 15 | 5 |
| Montage (min/unit) | 20 | 20 | 10 |
| Quality control (min/unit) | 5 | 5 | 5 |
| Total (min/unit) | 50 | 60 | 25 |

TL. Table 5 shows the production time of the products as 135 min for all and it is 50 min for dining table, 60 min for TV bench and 25 min for coffee table. When the weighted percentages of production time of products are calculated it is 0, 37 for dining table, 0, 45 for TV bench and 0, 18 for coffee table. Running expenses per product is calculated by multiplying monthly running expenses and weighted percentages of production time of products. It is assumed that 40% of running expenses is variable and 60% of it is fixed.²

Production times of products according to production processes are shown in Table 5 and it is 50 min for dining table, 60 min for TV bench and 25 min for coffee table. Firm completes these times while all the workers are working. For example; three workers who work at the montage department can assemble a dining table in 30 min and opening the minifix screw holes also handled at montage expense center. So, 24 dining tables, 24 TV benches and 48 coffee tables are produced in one day.

Application process of theory of constraints consists of five steps. These are accordingly; identifying the constraints, exploiting the constraints effectively, subordinating every related decision to the constraints, elevating the constraints and finally starting from first step again when the constraint elevated.

² Running expenses are separated as fixed and variable by using regression method.

Table 6
Identifying the constraints of the firm.

| Expense centers | Products | | | Actual capacity | Theoretical capacity | Difference | Capacity usage rate |
|-----------------|-------------------------|-------------------------|-------------------------|-----------------|----------------------|----------------|---------------------|
| | Dining table | TV bench | Coffee table | | | | |
| Cutting | $15 \times 240 = 3.600$ | $20 \times 200 = 4.000$ | $5 \times 440 = 2.200$ | 9.800 | 11.520 | 1.720 | 0.85 |
| Edge banding | $10 \times 240 = 2.400$ | $15 \times 200 = 3.000$ | $5 \times 440 = 2.200$ | 7.600 | 11.520 | 3.920 | 0.66 |
| Montage | $20 \times 240 = 4.800$ | $20 \times 200 = 4.000$ | $10 \times 440 = 4.400$ | 13.200 | 11.520 | (1.680) | 1.15 |
| Quality control | $5 \times 240 = 1.200$ | $5 \times 200 = 1.000$ | $5 \times 440 = 2.200$ | 4.400 | 11.520 | 7.120 | 0.38 |

Table 7
Calculating the contribution rate of products.

| | PRODUCTS | | |
|--|--------------|----------|--------------|
| | Dining Table | TV Bench | Coffee Table |
| Selling price (unit) | 400 TL | 430 TL | 130 TL |
| Direct raw material and supplies expenses (unit) | 139 TL | 120 TL | 55.5 TL |
| Contribution rate (unit) | 261 TL | 310 TL | 74.5 TL |

3.2. Application of theory of constraints

3.2.1. Identifying the constraints

First of all theoretical capacity and actual capacity of dining table, TV bench and coffee table should be compared at this step in order to identify the constraints. In Table 6 below, theoretical and actual capacity of dining table, TV bench and coffee table are compared in each expense center.

For example, dining table is processed for 15 min in cutting department and monthly 240 units is produced in the firm. TV bench is processed for 20 min in cutting department and monthly 200 units is produced in the firm while coffee table is processed for 5 min in cutting department and monthly 440 units is produced in the firm. Total actual capacity of the products is calculated as 9,800 min/month by multiplying product cutting times with monthly demand for the products.

As it can be seen from Table 6 there is a negative difference at the montage department which shows that actual capacity exceeds theoretical capacity. 13,200 min/month is needed in the montage department to be able to produce 240 dining tables, 200 TV benches and 440 coffee tables each month. But, theoretical capacity of montage department is 11,520 min/month. Since firm will not be able to meet customer demands, this constraint (bottleneck) is called capacity constraint.

3.2.2. Exploiting the constraints effectively

At this step, contribution rate of products and constraint times should be proportioned. Contribution rate is found by subtracting direct raw material and supplies expenses from sales price according to the theory of constraints.

In Table 7, contribution rate of products are shown. And contribution rates are 261 TL for dining table, 310 TL for TV bench and 74.5 TL for coffee table.

In Table 8, contribution rates of products are calculated according to constraint times. This is calculated by proportioning contribution rate to the montage department's time where constraint occurred. So, contribution rate of products according to constraint times are 13.05 for dining table, 15.5 for TV bench and 7.45 for coffee table.

According to the theory of constraints firstly product with the highest contribution rate should be produced. TV bench (15.5) is going to be produced first since it is the product with highest contribution rate. And then dining table (13.05) and coffee table (7.45) is going to be produced accordingly.

Theoretical capacity of the firm is 11,520 min/month. Required capacity for producing TV bench is estimated as 4000 min/month by multiplying monthly demand which is 200 with constraint time which is 20 min (constraint time equal to the process time of TV bench in montage department since bottleneck (constraint) occurred at the montage department). After this process capacity of the firm is 7520 min/month (11,520–4000). Afterwards, dining

Table 8
Calculating the contribution rate of products according to constraint times.

| | Products | | |
|--|--------------|----------|--------------|
| | Dining table | TV bench | Coffee table |
| Constraint rate (unit) | 261 TL | 310 TL | 74.5 TL |
| Constraint time (min) | 20 | 20 | 10 |
| Constraint rate/constraint time (TL/min) | 13.05 | 15.5 | 7.45 |

Table 9
Statement of income which organized according to theory of constraints.

| | Products | | | Total |
|---|-------------------------------|-------------------------------|-------------------------------|-----------|
| | Dining table | TV bench | Coffee table | |
| Total sales (sales price × monthly demand) | 400 TL × 240 unit = 96.000 TL | 430 TL × 200 unit = 86.000 TL | 130 TL × 272 unit = 35.360 TL | 217.360 |
| Direct raw material and supplies expenses (-) | 139 TL × 240 = (33.360) TL | 120 TL × 200 = (24.000) TL | 55,5 TL × 272 = (15.096) TL | (72.456) |
| Total contribution rate | 62.640 TL | 62.000 TL | 20.264 TL | 144.904 |
| Running expenses | | | | (127.068) |
| Direct labor cost | (13.500) | | | |
| Running expenses | (113.568) | | | |
| Net profit/loss | | | | 17.386 |

table whose capacity is 4800 min/month (240×20) will be produced. The capacity left after TV bench and dining table is 2720 min/month ($7520 - 4800$) and it will be used for coffee table. Only 272 ($2720/10$) unit of coffee table can be produced with the left capacity. Best product mix of the firm is going to be 200 TV benches, 240 dining tables and 272 coffee tables under these circumstances.

Statement of income is arranged after best product mix is determined according to theory of constraints for the firm. Statement of income is shown in Table 9 below.

As it is seen in Table 9, total sales are estimated by comparing sales prices with product mix which determined according to firm's theoretical capacity. It is estimated that firm makes profit after running expenses is subtracted from total contribution rate and the profit is 17,386 TL according to theory of constraints.

3.2.3. Subordinating every related decision to the constraints

Firm should only focus on the bottleneck (constraint) at the montage department at this step, since other departments are linked to that department to process properly. In other words, in order to prevent this bottleneck, all related decisions should be made at the right time at this step.

3.2.4. Elevating the constraints

Since the firm has capacity constraint which occurred at montage department, capacity of the department should be increased in order to elevate it. In order to eliminate this bottleneck, theoretical capacity (11,520) at the montage department should be increased be to actual capacity (13,200) at least. That is why firm decided to buy automatic jigsaw machine³ which costs 21,000 TL in order to increase the capacity 2000 min/month.⁴ As a result of this, running expenses have increased 350 TL⁵ per month and capacity constraint is elevated.

3.2.5. Starting from first step again when the constraint elevated

According to theory of constraints when a bottleneck is elevated, should be started from first step again. Because, this step checks if the decisions for elevating the bottleneck was correct as well as checking whether a

³ Automatic jigsaw machine opens minifix holes during the montage of the products.

⁴ Buying of this machine is an assumption.

⁵ Amortization of this machine is 5 years. Amortization for each month is $(21,000/5)/12 = 350$ TL according to normal amortization method.

Table 10
Identifying the constraints of firm again.

| Expense centers | Products | | | Actual capacity | Theoretical capacity | Difference | Capacity usage rate |
|-----------------|---|---|---|-----------------|----------------------|--------------|---------------------|
| | Dining table | TV bench | Coffee table | | | | |
| Cutting | $15 \times 240 = 3.600$ | $20 \times 200 = 4.000$ | $5 \times 440 = 2.200$ | 9.800 | 11.520 | 1.720 | 0,85 |
| Edge banding | $10 \times 240 = 2.400$ | $15 \times 200 = 3.000$ | $5 \times 440 = 2.200$ | 7.600 | 11.520 | 3.920 | 0,66 |
| Montage | $20 \times 240 = 4.800$ | $20 \times 200 = 4.000$ | $10 \times 440 = 4.400$ | 13.200 | 15.200 | 2.000 | 0,87 |
| Quality control | $5 \times 240 = 1.200$ | $5 \times 200 = 1.000$ | $5 \times 440 = 2.200$ | 4.400 | 11.520 | 7.120 | 0,38 |

Table 11
Recalculating the contribution rates according to constraint times.

| | Products | | |
|--|--------------|----------|--------------|
| | Dining table | TV bench | Coffee table |
| Constraint rate (unit) | 261 TL | 310 TL | 74,5 TL |
| Constraint time (min) | 20 | 20 | 10 |
| Constraint rate/constraint time (TL/min) | 13.05 | 15.5 | 7.45 |

Table 12
Recomposed income statement according to theory of constraints.

| | Products | | | Total |
|---|--|--|--|-----------|
| | Dining table | TV bench | Dining table | TV bench |
| Total sales (sales price \times monthly demand) | $400 \text{ TL} \times 240 \text{ unit} = 96,000 \text{ TL}$ | $430 \text{ TL} \times 200 \text{ unit} = 86,000 \text{ TL}$ | $130 \text{ TL} \times 440 \text{ unit} = 57,200 \text{ TL}$ | 239,200 |
| Direct raw material and supplies expenses (-) | $139 \text{ TL} \times 240 = (33,360) \text{ TL}$ | $120 \text{ TL} \times 200 = (24,000) \text{ TL}$ | $55.5 \text{ TL} \times 440 = (24,420) \text{ TL}$ | (81,780) |
| Total contribution rate | 62,640 TL | 62,000 TL | 32,780 TL | 157,420 |
| Running expenses | | | | (127,418) |
| Direct labor cost | (13.500) | | | |
| Running expenses | (113.918) | | | |
| Net profit/loss | | | | 30,002 |

new bottleneck has occurred after elevating the bottleneck. These steps follow each other like endless cycle which lead increase in profitability and cost minimization for firms.

After elevating the capacity constraint, all steps started again and constraints are identified again as shown in Table 10 below.

As it is shown in Table 10, automatic jigsaw machine increased the capacity 2000 min/month and capacity usage rate reached 87 %. This gives the firm an opportunity to produce according to monthly customer demands.

It is seen from Table 11 that when contribution rate is considered the sequence of products which will be produced is TV bench, dining table and coffee table accordingly. Total theoretical capacity is 15,200 min/month and 4000 min/month of this will be used for TV bench (20×200) and then 4800 min/month will be used for dining table (20×240). Capacity left after these is 6400 min/month and 4400 min/month capacity will be used for coffee table.

After the production sequence of the products is determined, firm's recalculated statement of income according to theory of constraints can be seen in Table 12 below.

As it is seen from Table 12, after elevating the constraint, profit of the firm increased to 30,002 TL from 17,386 TL. This indicates a 42% increase in the profit.

4. Conclusion

Profitability and getting bigger at the market is only depend on how effectively firms use their resources and minimize their costs due to technologic development and global competition. Since traditional cost accounting techniques are not sufficient for eliminating the bottlenecks, management and cost accounting tools like theory of constraints have been started to use by firms. According to theory of constraints firms are like chain, and weak links are the bottlenecks that prevent firms to reach their goals. If bottlenecks are managed efficiently then not only profit will increase but also resources will be used efficiently while minimizing the costs.

Theory of constraints is applied to a firm which operates at the Mediterranean Region in Turkey at furniture sector and following results have been found.

Monthly 240 dining table 200 TV bench and 440 coffee tables are demanded from the firm. And the firm can produce one dining table in 50 min, one TV bench in 60 min and one coffee table in 25 min. Firm can produce 24 dining tables, 200 TV bench and 440 coffee table on a daily average and prices/costs of these products are 400/130 TL, 430/120 TL and 130/55.50 TL respectively. Same raw material is used for all three products which go through the same processes which are cutting, edge banding, montage and quality control. Besides that monthly theoretical capacity is 11,520 min/month for all three products.

Theoretical and actual capacity of the firm is compared since the first step of theory of constraints is defining the bottlenecks. So it is found that the actual capacity of cutting expense center is 9,800 min/month, edge banding expense center is 7600 min/month, montage expense center is 13,200 min/month and quality control expense center is 4400 min/month. According to these results, 1680 min/month negative difference between actual capacity (13,200 min/month) and theoretical capacity (11,520 min/month) is detected. So the type of the bottleneck can be defined as capacity constraint since the constraint which prevents firm to reach its goals is shortage of meeting with monthly demand.

Contribution rate and their contribution rate according to constraint time of dining table, TV bench and coffee table is calculated at the second step of the application. It is found that the contribution rate of dining table, TV bench and coffee table are 261 TL, 310 TL and 74.50 TL respectively while contribution rate according to constraint time are 13.05 TL, 15.50 TL and 7.45 TL respectively. So the firm should produce the products according to their contribution rate which is first TV bench, then dining table and finally coffee table.

Number of products which supposed to be produced by the firm is determined after the order of product production process is defined. So according to the order of product production process, 200 TV benches 240 dining tables and 272 coffee tables should be produced. With reference to these findings, firm's statement of income was calculated and monthly profit was estimated as 17,386 TL.

At the third step it is focused on the necessary decisions to be taken by the firm in order to eliminate the bottlenecks and meet the monthly demand. It is assumed that firm may have decided to buy an automatic jigsaw machine in order to eliminate the capacity constraint. By this way bottleneck (constraint) will be eliminated and monthly capacity of firm will be increased 2000 min/month.

At the last step by turning back to first step and it is checked whether the improvement worked or there is any other bottleneck. Constraints defined again and firm's theoretical and actual capacity is compared. As a result of this check it is found that firm's capacity bottleneck eliminated.

Sequence of production is TV bench, dining table and coffee table according to defined order of product production process. Since capacity has increased firm can be able to produce more products and their amount will be 200 TV benches, 240 dining tables and 440 coffee tables. Firm's statement of income is recalculated and monthly profit is estimated as 30,002 TL instead of 17,386 TL.

Consequently it can be said that eliminating or effectively managing bottlenecks of the firms will increase contribution rate while decreasing stocks and running expenses which lead cost minimization. Moreover, it will also help firms to meet the customer demands in time which lead an increase in the profit.

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