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PRODUCTION & MANUFACTURING | RESEARCH ARTICLE

Different strategies to improve the production to reach the optimum capacity in plastic company

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Abstract: In this paper a case study of a company was studied to determine the main factors affecting its production capacity, and study their influence to improve the production capacity to reach the optimum. Different aspects were investigated, including the speed of the running machines, the number of workers running each machine, the operating shifts, the machines utilization and the working environment. Data were collected for the current situation, then suggested solution were implemented for each aspect and effect on improving the production capacity was realized. It was found that all these factors have significant effect on improving the production capacity. Machines should be utilized effectively and run at the optimum speed, to improve the production and avoid extra maintenance cost. Moreover, as the working environment is improved, the productivity of workers is getting better, which will be reflected on the company overall production. Resource allocation and rescheduling the working shifts helped significantly in improving the productivity as well.

Subjects: Supply Chain Management; Manufacturing Engineering; Operations Research

Keywords: production; optimum capacity; working environment; utilization; machines speed; working shifts

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PUBLIC INTEREST STATEMENT

Each company is expected to perform at its best. That is the main indication for its success. In this paper a case study of a company was studied to improve its production capacity to reach the best possible capacity. Different aspects were studied, including the speed of the running machines, the number of workers running each machine, the operating shifts, the machines utilization and the working environment. It was found that all these factors have significant effect on improving the production capacity. Machines should be utilized effectively by running them at the optimum speed, which keeps them running without need for extra maintenance or deteriorating them. Human factors are of major concern to improve the production. Working shifts can be rescheduled to be more appropriate for workers and enable them to produce more. Moreover, as the working environment is improved as the productivity of workers is getting better, which will be reflected on the company overall productivity.

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1. Introduction

Production planning aims at providing efficient and effective utilization of production resources, while meeting sales demand for products, and taking into consideration all significant variables that affect the manufacturing environment. The production planning process provides production targets and the corresponding resource allocations for each planning period. The production plan is often updated on a rolling planning horizon basis, incorporating new information as it becomes available. In order to support the execution of the production plan, linkages to the manufacturing planning and control system must be made. One of them is the link to Demand Management. Demand management must capture every source of demand against manufacturing capacity. The match between actual sales and forecast demand is monitored in the demand management module. As actual demand conditions depart from the forecast, the necessity for revising the production plan increases. The other linkage is Resource Planning. This encompasses long range planning of facilities. Involved in the translation of extended production plans into capacity requirements, usually on a gross or aggregate basis. Resource planning is directly related to production planning since in the short term, the resource available provides a set of constraints to production planning.

Capacity planning is central to the long term "success of an organization". After deciding what products or services should be offered and how they should be made, Management must plan the system's capacity. Capacity is the maximum rate of output for a facility. The facility can be a workstation or an entire organization. To prevent missing the opportunities for growth and profits, the operations manager must provide the capacity to meet the current and future demand. This requires making capacity planning or re-evaluating of the existing capacity in order to achieve his goal. The objective of capacity planning is to ensure as far as possible that the right resources are available when they are needed. Capacity plans are made at two levels; long-term and short-term capacity plans. Long-Term capacity plans deal with investments in new facilities and equipment. These plans look at least two years in the future, but construction lead times alone can force much longer time horizons. Short-term capacity plans focus on workforce size, overtime budgets, inventories, and other decisions.

Al Safa Plastics Packaging Company was chosen in this case study. This company which was established in 1994, manufactures printed and unprinted polystyrene lids and cups of unlimited shapes and sizes, as well as multi-layer and single layer extruded plastic sheets. Their goal is to gain the confidence and appreciation of their customers by emphasizing high productivity and excellent quality.

2. Literature review

There are new ways to test and evaluate the performance of production lines monitored like off-line inspection and Statistical Process Control (SPC). An off line method is quality control strategy that depends on inspecting the final product using control charts as an effective method of monitoring a process. Control charts enable the use of objective criteria for distinguishing background variation from events of significance based on statistical techniques. Much of its power lies in the ability to monitor both process center and its variation about that center, by collecting data from samples at various points within the process. Variations in the process that may affect the quality of the end product or service can be detected and corrected, thus reducing waste as well as the likelihood that problems will be passed on to the customer. With its emphasis on early detection and prevention of problems, SPC has a distinct advantage over quality methods, such as inspection, that applies resources to detecting and correcting problems in the end product or service, as was studied by Colledani and Tolio (2009). Guo et al. (2006) investigated that Good operating practices refer to multi factors like efficiency improvements. The effect of raw material improvement is to reduce the hazardous materials that enter the production processes especially in chemical production. The number of product to be scheduled, the time allowed in a process and the number of processes affecting the difficulty of scheduling were studied by Gascon, Lefrancois, and Cloutier (1998). They noticed that there is a global problem to optimize the scheduling decision of multi –product, multi -process for random manufacturing system. Research done by Chen and Wang (2009) showed that the yield learning processes of all the products should be observed and taken in consideration although the

yield learning process of a product can be accelerated by allocating more capacity or other resources. An effective capacity re-allocation mechanism is therefore required to guide capacity/resource re-allocation actions, so as to enhance the competitiveness of less competitive products at the least expense of higher competitive ones. The problem of improving the design process of factories was investigated by Mason, Baines, Kay, and Ladbrook (2005), through attempts to find all causes that affect the performance variation which reflected the capacity in other way. Chen and Cochran (2005) found that production plans are usually driven by manufacturing rules, with the objective of improving the factory's performance metrics. They studied the effectiveness of the three manufacturing rules which are: line balance, on-time delivery, and bottleneck utilization. The study results showed that the three manufacturing rules are most effective with respect to their corresponding metrics (Effective WIP, OTD, and Bottleneck Loading, respectively), but particularly when WIP distribution is in certain patterns. Baker (1998) studied different types of factory control algorithms which are: dispatching, scheduling, and pull algorithm. He described how all factory control algorithms used in industry can be implemented in a multi-agent hierarchy. Schedule evaluation techniques and related measures, together with simulation-based schedule evaluation solutions were studied by Pfeiffer, Kádár, and Monostori (2007). Their work resulted in that simulation, based on the proposed architecture, showed that rescheduling interval, the newly introduced variable schedule stability factor and the rescheduling threshold have significant effects on schedule quality as well as stability. Another study was made by Chen (2007) about evaluating the production by its yield, cost, price, demand, and production capacity. It was found that evaluating the competitiveness of a product with its yield is a reasonable idea. Hon (1982) found that monitoring and controlling the input and output of a manufacturing system is very efficient to optimize the production and the system objectives. Evaluation tactical production planning in supply chains was studied by Comelli (2008). They implement Activity Based Costing (ABC), cost drivers, and payment terms in order to estimate cash flow created by supply chain tactical production planning. In the manufacturing field, Karim, Smith, Halgamuge, and Islam (2008) made a research in order to contrast current manufacturing practices between two countries; Australia and Malaysia, and determine the practices that significantly influence their manufacturing performances. They conducted that product price has become a relatively less important factor for both Australian and Malaysian manufacturers today, and product quality and reliability (Q&R) have emerged as the main competitive factor. Wang and Chen (2009) have developed three mixed integer linear programming models with the objective either to minimize the total cost or to maximize the company profit of planning a resource portfolio. A nonlinear mixed integer programming (MIP) model for high-tech manufacturer developed by Hsu and Li (2009) to determine the optimal supply chain network design. Riezebos, Klingenberg, and Hicks (2009) could improve the productivity, quality and customer service in Toyota Production System by applying principles of Lean Production and the application of information technology. Choosing the best pull-type production control policy for a generic manufacturing line flow was investigated in by Sharma and Agrawal (2009), aiming to achieve a better utilization for resources by reducing non-productive time and work in progress inventory (WIP), and increasing customer service level. The goal of the study done by Li, González, and Zhu (2009) was to optimize the dedicated system through a simulation model, using a hybrid cell evaluated genetic algorithm (CEGA). They have found as a result that the dedicated remanufacturing is unstable and hard to control, which leads to poor economic performance with increased production cost. Improving supply chain (SC) performance is now a major interest for companies, due to the fact that coherent behavior between dependent members of the supply chain is greatly effective in achieving coordination, and thus reducing uncertainties. This has been discussed by Arshinder, Kanda, and Deshmukh (2009) in a case study that used SC contracts as tools to achieve the required coherence between members. Integration of production planning and scheduling was an issue raised by Li and Lerapetritou (2009, 2010) in two different ways: augmented Langrangian optimization, and decomposition framework. In both ways the aim was to improve the quality of decision making in the process operations, and to ensure the consistency between planning and scheduling decisions. The approaches given finally produced applicable solutions for the integration problem. Methods of improving the production and optimize the techniques and materials have been investigated by many researchers (Abu Jadayil, 2008, 2010, 2011a, 2011b; Abu Jadayil & Alnaber, 2013; Abu Jadayil & Flugrad, 2007; Abu Jadayil & Jaber, 2009; Abu Jadayil & Khraisat,

2010; Abu Jadayil & Mohsen, 2011; Fera, Fruggiero, Lambiase, & Macchiaroli, 2016; Khraisat & Abu Jadayil, 2010; Khraisat, Borgstrom, Nyborg, & Abu Jadayil, 2009). Many case studies have been made to study how to improve the production capacity.

Hailemariam and Yoseph (2015) reported a case study about leather manufacturing, where they studied how to improve the production capacity through building an efficient production planning and control system. Pisuchpen and Chansangar (2014) presented a study aimed to modify the plastic vision lens production line in order to improve its productivity. First work study and line balancing techniques were employed in order to improve the bottleneck point in the manufacturing process. But they could not achieve the target capacity. Then they implemented three other techniques; using the lowest unit production cost scenario, additional labor and machines were added into the bottleneck point of the production line. The productivity was then increased to reach the target value. Al Jubury (2016) presented a case study of Finnish company (Eurofins Viljavuuspalvelu Oy), where factors affecting the production capacity have been studied and analyzed. He used different techniques like bottleneck analysis, Overall Equipment Effectiveness (OEE), and Just in Time production. Using lean principles to improve the production capacity have been done by many researchers. Fahmi and Abdelwahab (2014) used lean manufacturing principles to improve the production in Steel industry. Also Nurrasjid and Adhiutama (2014) implemented the lean manufacturing principles in Indonesian pharmaceutical industry to improve the production capacity.

This paper presents many aspects that significantly affect the production capacity, and study the effect of improving each of them on the overall productivity. The results are based on real implementation of the theoretical ideas, and actual data are collected to support the conclusions.

3. Problem statement and solution technique

3.1. Problem statement
This case study is about Al Safa Plastics Packaging Co., one of many companies that encounter problems trying to reach a solution for optimum production capacity. Al-Safa daily faces different issues affecting its production; different problems in different areas like machines breakdowns due to insufficient or unprofessional maintenance, labor shortage or unskilled workers or bad working conditions, environment disturbances, and many other issues which are to be discussed and attentively covered in this study.

3.2. Objectives
The main objective in the study is to accomplish a significant approach by which we can study the factors affecting the productivity, and optimizing these factors to achieve the optimum production capacity. Initially it is needed to evaluate the existing production capacity of the factory, using the data for the production of all the machines during the whole year, through several techniques that are effective to make the estimation. After evaluating the current capacity, and studying the factors affecting the capacity from different angles and prospective, and estimating the percent of improvement in production by each factor, solutions can be suggested to improve the current productivity, by combining alternatives which significantly improve the productivity and concluding the best method to achieve the optimum production capacity.

3.3. Methodology
To achieve the goal of this study, the following scientific approaches and theories of the planning and production control procedures will be adopted such as machine utilization and capacity cushion, running at optimum speed, human factors and working environment conditions. Other approaches have been also developed to make the calculations, evaluate the system capability which needs improvement, make assumptions, and suggest key solutions. This is due to intensive research and digging through case studies and journal papers that discussed nearly similar projects and ideas to this case. Among those approaches the speed of machines, increasing it or decreasing it according to the available conditions at hand, and its relationship with production capacity and scheduled

maintenance (Lee & Lin, 2001), working conditions, workers ease and satisfaction, salaries and appropriate shifts, and the effect of all of that on their productivity as studied by other researchers (Furnham & Hughes, 1999; Shikdar & Das, 2003).

This research assumes the linear relationship between the production capacity and the studied factors; the speed of the machines, the number of workers running each machine, the utilization of the machines, the working shifts, and the working environment. The study started by investigating the current conditions affecting the production. Then each factor expecting to affect the production is modified one by one, and the effect of modifying that factor on the production capacity was studied. Each factor was modified and its effect on the production was monitored for almost five weeks. First the study investigated the optimum running speed of the machines. After they were determined, the production was studied under optimum running speeds of the machines. Then the number of workers running the machines was increased, and the effect on production was investigated. In the third stage, the working shifts were modified to improve the production capacity and save some labor costs as well. In the last stage, the working environment was improved both physically and improving the modes and attitudes of workers. The effect of each modification is recorded and studied separately.

The underlying motive of the investigators team to undertake the study was to assess and evaluate the current capacity and search for factors which enhance and improve that capacity. To achieve this, primary and secondary data were collected from the company in two stages (Hailemariam & Yoseph, 2015). In the first stage, qualitative research methods such as physical observations and structured interviews were conducted with employees working on different production machines to conceptualize and get clear idea about the production system and the working environment. Then, based on observations and interview findings, quantitative research, survey and quantitative data collection were done for prediction, explanations and generalization using numerical data. The data collected from all production areas and the targeted groups for resources of data included machine operators, production heads, technical managers, general manager, finance and personnel department, and some experienced workers from different working shifts. Documents were used to generate secondary more detailed data for production during the whole year. The data collected through qualitative approach were analyzed thematically to catch the common ideas and key points affecting the production capacity. The data collected from documents were used to get the exact results and the trends of production capacity.

Each time one of those factors was investigated and its changing effect on the production is studied, starting with the machines running speed, and trying to find the optimum speed, then adjusting the labor allocating for each machine, rescheduling the operating hours and shifts of the company, trying to improve the utilization of the machines and finally enhancing the working conditions of the workers and studying how this will improve the production capacity and quality as well.

4. Analysis of production capacity improvement methods

### 4.1. Increasing the speed of the machines

The speed of machines means the speed of two kinds of running machines in the factory, which are the Thermoforming machines, and the printers, that the third type; the extruders, is running 24 h a day throughout the whole year (except the maintenance time when it has to be stopped, which is a negligible time compared to a year running hours) and has a fixed capacity. The factory has three 50k thermoforming machines which were analyzed in this study, and the results of detailed calculations for these three machines are shown in the following sections.

4.1.1. Actual speed and production

Total monthly production in cartons for 50k machines for 2009 year is summarized in Figure 1.

Current production in units (according to types of molds):

Figure 1. Monthly actual production in cartons for 50k machines.
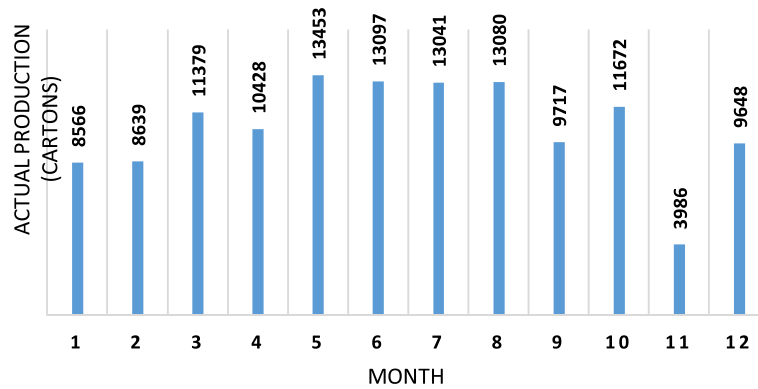
116 mm top diameter mold → 6 cavities

95 mm top diameter mold → 12 cavities

73 mm top diameter mold → 18 cavities

Total production = 36 cavities

To find the actual speed in which the machines were working, for example we take January production:

On average, each carton has 500 units, so we have: 8,566 cartons × 500 units = 4,283,000 units/month

4,283,000 units/month ÷ (30 days × 24 h × 60 min) = 99.14 units/min

Since we have 36 cavities in all 3 molds, then the speed of production for each machine (using all 3 molds) = 99.14 units/min ÷ 36 cavities = 2.75 hits/min

Similar calculations can be make for all months of 2009. Results are summarized in Table 1.

On average, the total running speed for each of the 3 machines during the year was: 3.39 hits/min.

4.1.2. Minimum speed
The minimum speed, by which the machines may work, according to the machines catalogs, is less than the running speed by 20%, so the minimum speed the machines could have worked by through 2009 is shown in Table 2.

Based on the minimum running speed of the machines, the minimum monthly production was calculated for January as follows, and summarized Figure 2.

2.2 hits/min × 36 cavities = 79.2 units/min

79.2 units/min × (30 days × 24 h × 60 min) = 3,421,440 units/month

Table 1. Monthly actual speed for 50k machines						
Month	**1**	**2**	**3**	**4**	**5**	**6**
Total speed (hits/min)	2.75	2.77	3.65	3.35	4.32	4.21
Month	7	8	9	10	11	12
Total speed (hits/min)	4.19	4.20	3.12	3.75	1.28	3.10

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Figure 2. Monthly minimum production for 50k machines.
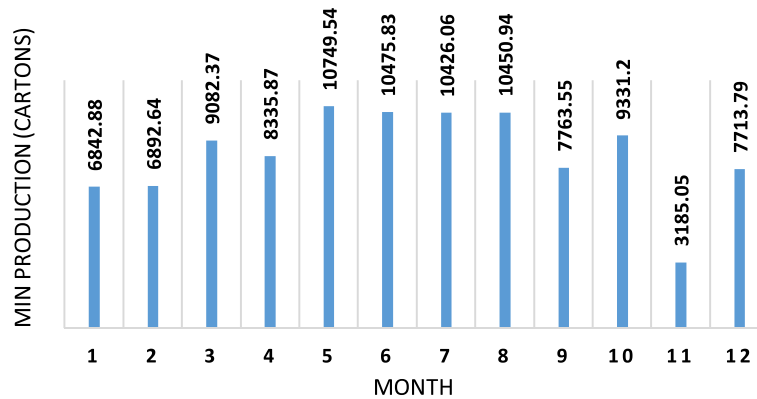
Table 2. Monthly minimum speed for 50k machines

Month	1	2	3	4	5	6
Total speed (hits/min)	2.20	2.216	2.92	2.68	3.46	3.37
Month	**7**	**8**	**9**	**10**	**11**	**12**
Total speed (hits/min)	3.35	3.36	2.50	3.00	1.02	2.48

Table 3. Monthly maximum speed for 50k machines

Month	1	2	3	4	5	6
Total speed (hits/min)	4.13	4.16	5.48	5.03	6.48	6.32
Month	**7**	**8**	**9**	**10**	**11**	**12**
Total speed (hits/min)	6.29	6.30	4.68	5.63	1.92	4.65

3,421,440 units/month ÷ 500 units = 6,842.88 cartons/month

4.1.3. Maximum speed
Also according to machines catalogs, the maximum speed is more than the running one by 50%. So, the maximum speed that the machines could have worked by through the whole year can be calculated and results are shown in Table 3. Based on the maximum speed, the maximum monthly production has been calculated and results are shown in Figure 3.

4.1.4. Suggested scenario for the machine speed
According to a case study that discussed similar issue same to this study (Abu Jadayil & Alnaber, 2013), it was suggested that the optimum speed can be reached by increasing the current one by 30%. Based on that, we can find the new speed as: 3.39 + 1.017 = 4.407 hits/min on average. And so, for the year 2009, results are summarized in Table 4. Comparison of the current, max., min. and suggested monthly speed for 50k machines is shown in Figure 4.

Based on suggested running speed, the monthly percentage increase in production can be summarized in Table 5.

On average the production will be increased by almost 30%, and the new monthly production is shown in Figure 5.

A comparison between the four cases of production, with current speed, with minimum speed, with maximum speed and with the suggested speed, was made, and results are shown in Figure 6.

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Figure 3. Monthly maximum production for 50k machines.
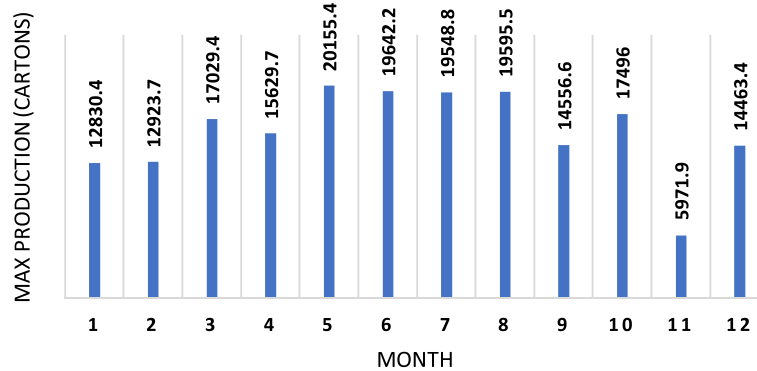

Figure 4. Comparison of the current, max., min. and suggested monthly speed for 50k machines.
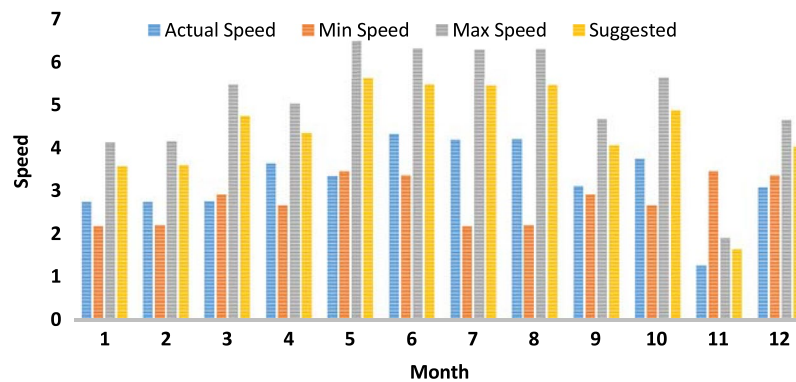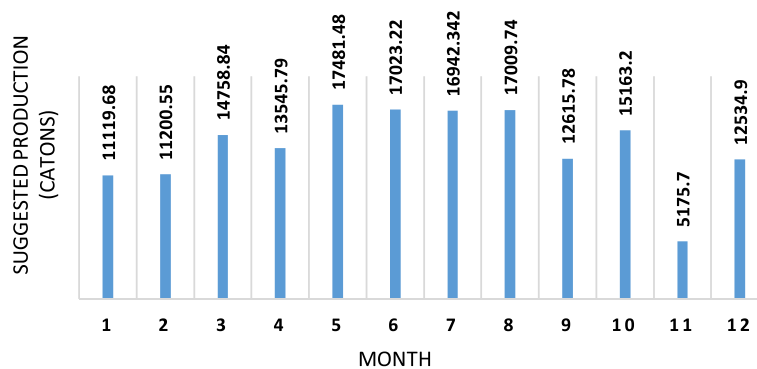

Figure 5. Monthly suggested production in cartons for 50k machines.

4.1.5. The cost factor

As suggested previously, increasing the speed may be the optimum solution theoretically. But on real ground, this may not be perfectly effective, because there is a major factor that must be taken into consideration, and might be an obstacle against any correction imposed on the system, and that is the cost. Increasing speed might affect several factors, and raise different critical issues, like cost of electricity, cost of maintenance due to increased number of breakdowns especially that the machine age might decrease if its working load gets higher than usually it is. Unfortunately, we do not have this specific cost data to do calculations and see the difference, but we can expect that the running cost will increase and it will negatively affect the outcome of the factory.

4.2. Increasing the number of workers on each machine

The factory has seventeen machines; eight printing machines with three operators for each, three machines of type 50k with two operators work on each, one machine of type 70k with four operators

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Table 4. Monthly suggested speed for 50k machines						
Month	**1**	**2**	**3**	**4**	**5**	**6**
Total speed (hits/min)	3.58	3.60	4.75	4.36	5.62	5.47
Month	**7**	**8**	**9**	**10**	**11**	**12**
Total speed (hits/min)	5.45	5.46	4.06	4.88	1.66	4.03

Table 5. Monthly suggested production and percentage of increase for 50k machines						
Month	**1**	**2**	**3**	**4**	**5**	**6**
Production (cartons)	11,119.68	11,200.55	14,758.84	13,545.79	17,481.48	17,023.22
Production increase (%)	29.81	29.65	29.70	29.89	29.94	29.97
Month	**7**	**8**	**9**	**10**	**11**	**12**
Production (cartons)	16,942.34	17,009.74	12,615.78	15,163.20	5,175.70	12,534.90
Production increase (%)	29.92	30.04	29.83	29.91	29.85	29.92

work on it, two machines of type D42 with one operator for each, two machines of type G with one operator for each, and one machine of type 37-10 with two operators work on it.

There are six operators work on the 50k three machines. If it is assumed that the effort of the workers on this type of machines are equal because they are supposed to do the same task, then it can be claimed that each operator can make a certain amount of cartons on his machine each month. For example this amount for January is:

Total number of cartons produced/Number of workers on these machines = 8,566/6 = 1,472.6 units/ worker in January.

Similar calculation for the whole year, and results are summarized in Table 6.

Theoretical speaking, if one more worker can be added for each machine then results for the production which can be found are summarized in Table 7. For example, in January the total number of units that should be produced, if there is nine workers are assumed instead of six, can be calculated from the following equation:

Total number of cartons = (monthly cartons per worker) × (nine workers) = 1,472.6 × 9 = 12,849 units

Figure 6. Total monthly production for 50k machines.
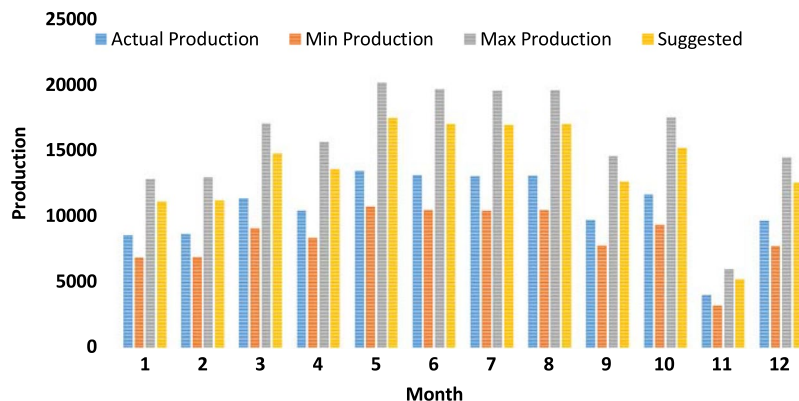
Table 6. Monthly actual production per worker for 50k machines

Month	1	2	3	4	5	6
Production	8,566	8,639	11,379	10,428	13,453	13,097
Monthly production/worker	1,472.60	1,439.83	1,896.50	1,738.00	2,242.16	2,182.83
Month	**7**	**8**	**9**	**10**	**11**	**12**
Production	13,041	13,080	9,717	11,672	3,986	9,648
Monthly production/worker	2,173.50	2,180.00	1,619.50	1,945.30	664.30	1,608.00

Table 7. Monthly 50k machine production, currently and after add one more worker

Month	Current production	Production when adding one worker
1	8,566	12,849
2	8,639	12,959
3	11,379	17,069
4	10,428	15,642
5	13,453	20,180
6	13,097	19,646
7	13,041	19,562
8	13,080	19,620
9	9,717	14,576
10	11,672	17,508
11	3,986	5,979
12	9,648	14,472

It can be clearly seen that the monthly production has increased by 50% as the number of workers on each machine is increased by 50%. On the other hand, the increase in the cost of the extra worker salary should be calculated as well. In the current situation the company has only six workers for these three machines, and the monthly salary of each one is $150. So they pay them $900 as total salaries, but in the second suggested situation the salaries will increase to $1350 which means it has increased by $450. Although, the profit margin in each cartoon produced by will be the same, as the current number of workers on all machines will increase, as the total profit will increase as well.

Implementing this principle on real, by adding one worker on each machine in one month, resulted in increasing the production in that month, but in different percentages than those expected theoretically. Results for actual implementation of this suggestion are summarized in Table 8.

Although the actual increase in production is less than the theoretical values, adding one more worker for each machine of any machine type will increase the production capacity by 9 to 47%.

4.3. Modifying the working shifts
Al-Safa plastic company works for 24 h/7 days a week, the working hours are distributed over two shifts per day; the first shift from (8 am – 8 pm) and the second shift from (8 pm – 8 am), the break hour is 2 hrs are for each shift: half hour in the morning, 1 hr at the middle of day, half hour in the evening. So there is a possibility to reschedule the working hours over three shifts instead of two; each shift is 8 hrs with single break hour which is enough and convenient. The current situation shift has eight working hours with a double break hours but the alternative suggestion is eight working hours with single break hour which is good for worker according to the effort, the performance and the amount of production. Al- Safa Company has 80 workers for the two shifts, so the distribution of those workers on three shifts will be better such as the first two shifts contain 25 workers for each, and the third shift (night shift) contains 30 workers. That distribution is based on the production data

Table 8. Percentage increase in production for each machine type when adding one more worker for each machine				
Machine Type (#)	Current no. of workers	Suggested no. of workers	Theoretical increase in production (%)	Actual increase in production (%)
Printing (8)	24	32	33	12
50k (3)	6	9	50	47
70k (1)	4	5	25	9
D42 (2)	2	4	100	17
G (2)	2	4	100	15
37-10 (1)	2	3	50	14

from the factory, which shows that the night shift is the most active shift with higher production than the other two shifts. So more workers are expected to work during that night shift. The effect of this suggestion will be reflected on the productivity, the financial situation of the factory, how much the cost of payments for workers, production needs and other issues. When the worker works for single shift of less hours he/she takes less than the regular salary because the number of working hours reduced and the payment system in the factory depend on working hours. So, when the worker works for less hours which means less salary; this will result in reducing the labors cost and increase productivity. Moreover, the workers with less number of working hours have higher efficiency, less effort and less exposure for injures that the worker will be in a safe working environment. It has to take into consideration that the double hours break has more positive reflection on the performance and attitude of the work than the single hour break. This issue can be resolved partially if the one hour break is divided into two brakes, 30 min each. Each break of 30 min can be taken after 3 h of working. Then the worker will be comfortable, relax and more productive. The workers were asked about this suggestion, and after few days of trying it, they liked it and their response was positive, and they think it is enough to relax and release stress. The other suggestion is to take into consideration the age of the workers when distributing them over the shifts. Older workers are preferred to work at the morning shifts and the young workers work at night shift. Because age has a strong effect on the productivity such as the ability to keep standing in front of the machine for a long period of time and maintain it. Furthermore, young workers are more productive, so it's preferable to use them at night shift. Following these strategies, would result in reducing the labors cost and increasing productivity.

For the current scenario of two shift system, and since the total numbers of workers in the factory are 80 workers, the total salaries paid were calculated as follows:

The first shift from **(8 AM – 8 PM)**: from **(8 AM – 4 PM)** are fixed working hours and from **(4 PM – 8 PM)** are over time.

The second shift from **(8 PM – 8 AM)**: from **(8 PM – 4 AM)** are fixed working hours and from **(4 AM – 8 AM)** are over time.

The cost of working hour during working time: $150/240 h = $0.625/h (for one shift)

Over time cost = $0.625 × 1.25 = $0.78125

Note: (1.25) is according to the factory overtime policy.

The total salary for each worker = $150 + $(0.78125 × 4 × 30) = $243.75

Total money paid = total numbers of workers had an overtime in these two shifts × total salary for each worker = 80 × 243.75 = $19,500/month

The suggested scenario is hiring 40 more workers and redistributing workers over 3 shifts with no overtime. Then the total salaries paid can be calculated as follows:

The first shift: **(8 AM-4 PM).**

The second shift **(4 PM – 12AM).**

The third shift **(12 AM – 8 AM).**

Since there is no over time so the salary remains fixed ($150 / month)

Total salaries paid in month = 150 × 120 = $18,000

The percentage of reducing the labor cost = (19,500 – 18,000)/ 19,500 = 0.077 = 7.7%

Comparison between 2 shift and 3 shift schedule is summarized in Table 9.

So, hiring 40 more workers will safe almost 7.7% of money paid for salaries, but what is more important is efficiency of workers and will that improve the productivity. The company adopted this suggestion for one month, and asked its workers to work on the first two shifts and hired part time workers for the third shift. They noticed an increase in productivity around 20%. The reason for that, a worker cannot work with same performance over 12 hours, and most of the overtime working hours the workers' performance is much lower than the regular working hours.

4.4. Improving the machines' utilization

The Utilization is the degree to which equipment, space, or the workforce is currently being used, and it is measured as the ratio of average output rate to maximum capacity. The utilization rate indicates the need for adding extra capacity or eliminating unneeded capacity.

$$\text{Utilization} = (\text{Average output rate}/\text{Maximum capacity}) \times 100\% \qquad (1)$$

Utilization definition given in Equation (1) is equivalent to the ratio of the actual production achieved at certain period of time, and the ideal production rate multiplied by the available time for production during that period of time. The maximum capacity is the greatest level of output that a process can produce at a specific period of time. For the factory machines, it means running the machines at the maximum speed for 24 hours a day, 30 days a month.

4.4.1. Calculating the machines' utilization

It is needed to find the utilization for each machine in the factory. An example of calculating the utilization of machines, using data from Table 10, utilization for 50k machine is calculated as follows:

Average output rate for the 12 months of 2009 = 10,558.83 cartons

Maximum capacity (from the maximum production data) = 20,155.4 cartons

Utilization = (10,558.83 /20,155.4) × 100% = 52.39%

4.4.2. Calculating the capacity cushion

Capacity cushion is defined as the amount of reserve capacity a process uses to handle sudden increase in demand or temporary losses of production capacity; it measures the amount by which the average utilization (in term of total capacity) falls below 100%.

$$\text{Capacity cushion} = 100\% - \text{Average utilization rate} (\%) \qquad (2)$$

The utilization of all types of machines were calculated and results shown in Table 11.

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Number of shifts	Number of fixed working hours per month (hrs/month)	Number of over time working hours per month (hrs/month)	The fixed salary for each worker per month $/month	Total number of workers for each shifts	Number of workers who had an over time working hours	Total Money paid as Salaries ($)
Table 9. Comparison of working hours and costs of 2 shifts and 3 shifts schedules						
2	8 × 30 × 80 = 19,200	4 × 30 × 80 = 9,600	150	40	40	19,500
3	8 × 30 × 120 = 28,800	0	150	40	0	18,000

Table 10. Monthly output in cartons for 50k machines												
Month	1	2	3	4	5	6	7	8	9	10	11	12
Output (Cartons)	8,566	8,639	11,379	10,428	13,453	13,097	13,041	13,080	9,717	11,672	3,986	9,648

The Average utilization rate was found to be 36.66%, and the capacity cushion was found to be 63.34%. An important fact here is that it is not only enough to run the machines at their maximum speeds, but almost to use them as long as they are ready to be used and able to produce. That means we still have the chance to improve the production by an average of 63.34%. As discussed earlier, we might go for an optimum speed rather than the maximum, and so we can improve the production by an average of 33%.

4.5. Working environment

Making workers happy means that people will take more pride in their work, feeling excited while doing their jobs and be more productive. Happier employees mean happier employers, since the employer will not lose money due to lower efficiency and lost productivity. How working conditions affect employees' productivity have been studied in the following sections.

4.5.1. The effect of improving the employee morale

Most people thrive when feeling appreciated. Employee morale can be enhanced by showing appreciation for what they are doing in simple ways, such as rewarding an employee by saying, "job well done," or, "thank you for the good work". Another way to show appreciation and boost employee morale is by being friendly and interested in your employees. A warm smile and a sincere query about how one is doing will for sure motivate employees. Knowing people's names and personalizing the work environment inspires employees, who will compete to help you.

Encouraging social interaction between employees and immediately resolving conflicts is another way to improve employee morale. Social events such as office picnics and softball games create a sense of camaraderie between employees. Social interaction positively influences cooperation and a general enthusiasm about coming to work every day. Isolation, on the other hand, causes depression and a lack of motivation. The employee morale can also be improved by offering reward incentives. A job well done might be rewarded with a gift card or a cash bonus. This reward can come as a surprise to the employees who earn it, or it can be announced as a sort of game or contest. Having a goal to work towards that directly benefits the employee, can help create enthusiasm, which tends to be contagious.

A very important factor in improving employee morale is the work environment. Psychological research shows that atmosphere greatly and directly affects the motivation level and feelings of wellbeing of the employees in a workplace. When possible, providing comfortable and aesthetically

Table 11. Utilization of machines during the whole year						
Machine type	**50k**	**70k**	**37/10**	**D42**	**G**	**Printing machines**
Utilization (%)	52.4	21.5	42.95	30.07	17.65	55.39

pleasing furniture is one way that researchers suggest to motivate people. Lighting, flowers and artwork can also help improve employee morale.

All that was explained for the factory management to take it into consideration. They took it seriously and started a plan to improve the employees' moral, by enhancing social activities and formal participation by the company in all social events of the employees, having group lunch for 30 minutes, where managers and workers all have lunch together, and organized two picnics within one month. A social committee was formed to organize social events for the employees. A weekly award was created for the best employee, which enhanced all employee to do their best to win that award. A complaint committee was created to receive any complaints from employee and listen to their suggestions.

Within two months, it was found that the productivity was improved by almost 6%, and turnover was reduced by almost 80%, which gave more stability for the working environment. Of course as time proceeds as the productivity is expected to improve.

4.5.2. The effect of noise
Noise can be termed as unwanted or undesirable sound, because of its adverse effects in our living and working environment. Unfortunately a large number of people work in Industrial plants, where the noise level found consistently high, and the exposure takes place regularly for about 8–10 hours a day, year after year, the effects cease to be temporary and even permanent hearing loss, rather than leading to significant adverse physiological effects. Studies on human working in Noisy Environments have reported an increased incidence of heart disease, accident at work, inefficiency, feeling of annoyance, irritation, speech and work interference, sleep disturbance, cancer, headache, tension, digestive, respiratory, nervous problems and so many psychological effects on human system. Much of the work is being done all over the world to limit high level environmental and occupational noise levels within the comfortable limits for humans. But in developing countries, little work being done in this regard. Also due to lack of regulatory laws to limit high level noise and general unawareness of workers about ill-effects of noise, the owners of the plants pay negligible attention to provide health and safety measures to their workers against high level noise. One should expect vigorous action against high level noise in industries, but due to poverty, the workers are compelled to work under such environmental conditions.

The company was advised to implement the International Noise Emission Standards which are designed to control the noise emitted by specific machines, such as aircraft, cars or industrial equipment. To improve the working environment, the company is advised to follow the environmental noise exposure standards and legislation which are normally devised by national or local authorities to provide an acceptable noise environment for their specific conditions. Noise emission levels depend not only on the noise emitted by particular sources, but also the distance from the source, and the use of noise attenuation measures such as Noise barriers or double glazing which may be required to meet national or local noise emission Standards. Based on that, this company should work on improving the working environment and eliminating or reducing the noise to the acceptable standard levels. That would create a healthier environment for working and so the productivity is expected to be highly improved. The company have taken these recommendations seriously and started the work environment improvements. Although only some enhancement have been made, the overall production has been improved by 9%, most of that have resulted from reducing the defects which were used to appear in the production. On the other hand, the employees' attitude and

feelings started to be much better, and they started to look more comfortable, and for sure that will be reflected on their productivity in the next few months.

5. Discussion and analysis of results

5.1. Increasing the speed of the machines

As the machines' speed is increased by 30%, it can be obviously observed that the productivity will increase by almost 30%, which means increasing in the profit of the factory. On the other hand, the drawbacks of increasing the machines' speed should be taken into consideration. As increasing the machines' speed will affect many aspects of the production process; just like increasing maintenance requirements of the machines, and so the reduction of the ages of the machines. In this research the effects of increasing machines speed on machines vibrations and the implications for bearing fault detection have been investigated. These effects are important to understand because when ignored they can significantly hinder the ability to detect bearing faults. For those machines which running speed have been increased, it was noticed that increasing machine's speed can directly and nonlinearly alter the level of machine vibration. This is due to differences in mechanical damping and resonance at various machine speeds. While this effect is difficult to notice in healthy machines, it can become significant as bearing health degrades. An additional effect that speed can exert is on the rate of development of a bearing fault. Variations in speed can actually retard or temporarily mask the increase in machine vibration due to a bearing fault. This phenomenon is observed in experimental trials as the bearing fault enters an advanced and more deteriorated stage.

As a result of increasing the machines speed, it may affect the ages of the machines, which might decrease, and more efficient maintenance strategy is needed to keep the machine in good running conditions. Consequently, that will increase the cost of the maintenance. All those factors have been taken into consideration, and so the maximum, suggested or optimum, and the minimum speeds have been studied. It is recommended to use the optimum speed since it has the least effect on the maintenance and ages of the machines, and so the expected average improvement in production will be around 30%.

5.2. Increasing the number of workers

According to some cases that have been studied to increase the number of workers for each machine in a logical way, and their effect on the cost which represented by the new workers' salaries, it has been found that all machines have had an increase in their production by adding one more worker for each, but that increase of the machine production has minor effect on the overall factory production, except in the case of 50k machines. Adding one more worker on each of the 50k machines resulted in 50k machines productivity increase by 47% and the overall factory production increase by almost 40%, simply because 50k machines represent a bottleneck. Consequently, it does worth to add one more worker for each 50k machine but not all machines. In that way the bottleneck problem can be solved by adding more workers on the 50k machines that have the highest load and so increasing the productivity of the factory.

5.3. Modifying the number of working shifts

The company working shifts have been scheduled in a scientific way so that the factory can get better performance from the workers. There were two shifts and two break hours for each shift. It was suggested to make the number of shift three with taking in consideration the number of workers, the age, and the break hours in each shift, where the current workers cover the first two shifts and hiring 40 more workers to cover the third shift. It was also noticed that if the factory do that they will get better productivity with lower cost for the factory management. Where the productivity of the factory is increased by 20% and a saving in salaries of 7.7% were made. However, the new suggestion will make the workers more comfortable, but they will less paid.

5.4. The machines utilization

The utilization for all machine types have been calculated, and it was found to be from 17% in case of G machines up to 55% in case of printing machines, with an average of 36%. That means almost 63% of the utilization is lost. The utilization of the bottleneck machine the 50k machines is only 52%. The utilization can be 100% if all machines are running all the time at the maximum speeds, but since that is not practical, the optimum speed can be used to improve the utilization of the machines. If the optimum speed is used for all machines, then the production can be improved by almost 33%.

5.5. The environment effects

Many managers and labor supervisors have fallen under the mistaken impression that the level of employee performance on the job is proportional to the size of the employee's pay packet. Although this may be true in minor cases, numerous employee surveys have shown the contrary. In fact, salary increases and bonuses for performance, in many cases, have a very limited short-term effect. The extra money soon comes to be regarded not as an incentive but as an "entitlement". There are other factors that when combined, they provide a more powerful determinant of employee performance. When these other factors are missing or diluted, the employee does come to work only for a pay-check. In this case, the employee is present at work in body only, leaving their minds outside the gate.

It is the quality of the employee's workplace environment that most impacts their level of motivation and subsequent performance. How well they engage with the organization, especially with their immediate environment, influences to a great extent their error rate. Moreover, their level of innovation and collaboration with other employees, absenteeism and, ultimately, how long they will stay in the job. Many studies have revealed that most employees leave their organization because of the relationship with their immediate supervisor or manager and the bad environment.

In this case study, it is suggested to the factory to improve the employees morale should find better facilities for the workers to motivate them to do the tasks in a good morals. An example of environment issues that has been improved is the air conditionings. They have had some redesign for some workplaces to make it more comfortable for the workers which will affect positively the productivity. Improving the employees' moral resulted in improving the productivity by almost 6%, and reducing the workers turnover by almost 80%. Moreover, reducing the working environment noise and installing some air conditioning resulted in improving the productivity by almost 9%.

6. Conclusions and recommendations

6.1. Conclusions

Based on the research results, the main conclusion can be summarized in the following:

- In this research a real life problem has been studied, where weak production planning has resulted in inefficient use of production capacity and employees' dissatisfaction.
- The main factors affecting the production capacity are the speed of the machines, the number of workers on each machine, the shifts schedule, machines' utilization and the working environment. These factors have been studied and their effect on improving the production capacity have been determined.
- Running machines at the optimum speed improves the production by almost 30%. Increasing the number of workers who run the bottleneck machines by one worker for each machine can improve the production by 40%. Rescheduling the working shifts and hire more workers saves 7.7% of the workers' wages and increases the production capacity by 20%. Utilization the machines at the optimum speed can increase the production capacity by 33%. Improving the workers morale can increase the production capacity by 6%, and reduce the workers turnover by 80%. Moreover, improving the working environment and reducing the noise can improve the production capacity by 9% mainly as a result of reducing the defects.

6.2. Recommendations

Defining the problem, analyzing it, finding all possible alternatives, then choosing the best alternative that gives the highest production capacity with the minimum costs, are the steps to reach feasible solution for the problem in hand. The following are some recommendations that may be helpful in improving the current production system:

- Improving the utilization of the production machines, and running them at the optimum speed.
- Building and adopting an effective maintenance strategy to protect the production machines and extend their running life.
- Adding one more worker on the bottleneck machines. That would improve the production significantly.
- Building an efficient scheduling system for the working shifts, taking into consideration improving the production and human factors as well.
- Improving the working environment is very essential in improving the production capacity and quality as well.

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Citation information
Cite this article as: Different strategies to improve the production to reach the optimum capacity in plastic company, Wisam Abu Jadayil, Walid Khraisat & Mwafak Shakoor, *Cogent Engineering* (2017), 4: 1389831.

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