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Production and Operations Management: A Historical Overview

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Abstract

Production and Operations Management is a functional field of business with a (relatively) long history and development. This development is briefly discussed and an attempt is made to discern new trends. Some interactions with Operations Research are clarified.

1. Introduction

In this paper we give an overview of Production Management and briefly discuss some of its main links with Operations Research. We do not intend to present a complete and exhaustive analysis, but only a general picture. We start with a definition of Production Management, scan the history of the field, deal with some recent developments, and, in conclusion, attempt to say something about the future.

Production Management deals with the design, operation, and improvement of the production systems in a firm. These systems create products or services. Therefore, Production Management is perhaps not an appropriate term. A better name would be Production and Operations Management, or simply Operations Management. This name implies that the study of all supporting logistics is also part of the discipline (Wild, 1991). Yet in this paper we will not completely disregard "Production Management" because we intend to mainly discuss the manufacturing industry.

Production and Operations Management is a fundamental field of business with clear line management responsibilities. Therefore, it is not the same as Operations Research (or Management Science). This is a somewhat more theoretical discipline that deals with quantitative methods to decision making in all fields.

2. The Past

Some scholars see the beginnings of Production and Operations Management in the 18th century with Adam Smith, at the beginning of the Industrial Revolution. In his famous book "Inquiry into the Nature and the Causes of the Wealth of Nations", Smith extensively discusses the production of pins. He explains how specialization and division of labor greatly contribute to an increased production rate. But Adam Smith must have been expressing what had been common knowledge for centuries.

To illustrate this, we use a rather unusual source : The Fairy Tales of the Grimm Brothers (1843). In some fairy tales the hero or heroine faces a difficult production task. This might be an immense cleaning job, the weaving of a wonderful dress, preparing a huge amount of food, leveling a mountain, or changing flax into gold. These tasks are easily solved by magic and allow the hero to live happily ever after. Magic should be equated with the concept of modern technology. Our ancestors rightly guessed that some new immense forces were needed to adequately attack the production problems of mankind. Nowadays, thanks to modern technology, producing lots of food or moving mountains, has become feasible. Only changing flax into gold remains somewhat more difficult.

There is one fairy tale of particular interest, even though it does not rely on magic. It is the story of The Three Spinsters.

A girl is picked up by the queen of the country, who requires her to spin three large rooms full of flax in three days. If she succeeds, she may marry the crown prince. After two days she has barely made a start with the horrible task and the situation looks dramatic. Then three strange creatures appear, three old women. One has a very broad and flat foot, the second has a large lower lip, and the third a very thick thumb. They offer the girl to do the job for her on the condition that she'll invite them to her wedding. The girl agrees and the spinsters start. The tale describes their way of working : *"The first old lady pulled the thread and turned the wheel with her flat foot; the second moistened the thread with her lower lip, the third wound it on a loom and hit the table with her thumb - and whenever she did so a loom of thread fell to the floor, thread of the finest quality."* In one day the job is done and a few days later the wedding celebrated. The bride introduces the spinsters as her nieces. When the crown prince learns that their strange deformities are the result of spinning, he wisely decides that his wife will never have to work again.

According to some learned professors, this fairy tale is Teutonic in origin, and very, very old. Yet it clearly expresses the principle of division of labor and specialization. With a little bit of imagination, the team of spinsters appear to us as a foreshadow of the moving assembly line of Henry Ford of 1913[1]. Was it not Ford who complained of having to work with human beings when all he needed was a hand or a foot? The fairy tale also stresses something that was subtly ignored by both Smith and Ford : specialization often leads to deformed human beings, either physically or mentally.

Specialization and division of labor into smaller and smaller units have been guiding principles throughout the 19th century and most of the 20th century. It was attempted in product manufacturing, in product design, in service businesses, and in administrations. But at the beginning of this century, something important was added. Frederick Taylor (1911), an American engineer, pioneered the use of time-and-motion studies to increase efficiency. He

[1] Some will claim that the Venetians invented the assembly line to equip their battle galleys in the late Middle Ages.

proposed to carefully study all the work in a factory and to determine "scientifically" how much could be done by using the most economical rate and movements. Many of his experiments became famous; so his study at Bethlehem Steel to found "the science of shoveling". Workers who shoveled at Bethlehem owned their own shovels and would use the same one for any job : lifting heavy iron ore or lifting light rice coal. After considerable study, Taylor designed shovels to fit the different loads. For example, shovels for iron ore were given short handles; those for the light rice coal were given a broad scooped shape and longer handles. Also optimal loads in function of distance and height were specified (Niebel, 1993). Through such studies management was in a position to impose the most appropriate equipment and movements, and to financially reward or punish the worker if he did or did not meet the standards. Thus, the hands and feet that were needed in the factory had to move according to precise prescriptions, like puppets on a string.

This type of organization leads automatically to large and very hierarchically structured firms and factories. Economy of scale can then be used to the utmost. Any change has to be avoided in such a factory since it interrupts the regular, standardized movements. In accordance with Harris' formula (1913) machine setups and changeovers are avoided and large batches of the products are produced. This, in turn, requires that large inventories of parts and products are kept. And it takes a long time for a part or product to flow through the factory. The production patterns are therefore stable, but the factory is very inflexible.

Many firms had their production organized along these lines until the late 1970's. Some change, however, was triggered by the so-called Hawthorne studies conducted by Elton Mayo and F.J. Roethlisberger in America in the late 1920's and early 30's. These experiments were designed by sociologists and not by engineers, to study the effects of certain environmental changes on the output of assembly workers. To the surprise of the researchers, changing the level of illumination for example, had much less effect on output than the way in which the changes were introduced and explained to the workers. In some cases a reduction in illumination led to an increased output because workers felt an obligation to their group to keep output high. So, the researchers discovered that behind all the hands and feet working in the factory, there were real human beings with human feelings. These discoveries had implications for work design and motivation. After a while, large firms started to establish personnel management and human relations departments. Today's Job Enrichment Programs have their origin in the Hawthorne studies.

The 1970's saw the introduction of computers in operations problems. For manufacturers the big breakthrough was the application of Materials Requirements Planning (MRP). IBM and APICS, the American Production and Inventory Control Society, enthusiastically promoted MRP-software until it became a kind of crusade (Wight, 1983). MRP uses a computer program that ties together all the parts required to assemble complicated products. This program enables production planners to adjust production schedules and inventory purchases more easily in order to meet the changing demands for final products.

The appearance of the computer is of course significant, but MRP was not a very important innovation. MRP did not substantially alter the classical mastodontic factories with their hierarchies and inflexibilities. The real change came from a rather unexpected corner : Japan. It was Just-in-Time production coupled with Japanese quality management that shook the old production practices of the manufacturers.

Just-in-Time (JIT) is an integrated set of activities designed to achieve high-volume production by using small inventories of parts that arrive at the workstation just in time for use (Monden, 1983). Therefore, in JIT-production, the changeover times of the machines are carefully studied, and by means of organizational and technical manipulations, they are reduced to minimal sizes (Shingo et al., 1985). Because of this, production lots and inventories of parts can be reduced. Meanwhile, workers will aggressively seek to eliminate all causes of defects. The production process becomes smoother, without major interruptions. All rigidity disappears and the process becomes lean and flexible. The production planners can quickly adjust the production schedules to meet changing demands for final products. In the end, both cost and quality improve.

Japanese managers were apparently successful in eliminating all kinds of waste in the manufacturing process, but also in motivating the workers to care about the whole process. Total Quality Control concepts (Oakland, 1993) could be implemented. How can Japanese workers be made so alert to the issue of quality? And also, how can Japanese customers be so obsessed about quality? Their culture and especially their Buddhist Zen religion have a lot to do with this. Zen is imbedded in daily life, in everyday actions. Zen mind is practical and concrete and imposes a perfecting of technical skill. So there can be Zen in calligraphy, in archery, in flower arrangement, in swordmanship, and -why not?- in car manufacturing. Another important factor is certainly the different attitude and philosophy of trade unionism in Japan; and the smaller impact of Marxism.

3. The Role of Operations Research

As mentioned earlier, Operations Research deals with decision making in quantitative terms. Operations Research or Operational Research as it is called in Great Britain, developed as an independent and multi-disciplinary field in the British armed forces in the period 1937-1945, when military operations, especially bombing operations and radar protection needed to be optimal (Larnder, 1984; Keys, 1991). After the War, many operations research concepts, such as model building, data collection, simulation, optimization, and sensitivity analysis, became common in business and manufacturing, especially in America. A major development was G. Dantzig's simplex algorithm for linear programming problems in 1947. Unfortunately, in these post-war years Operations Research became a little "academic" and less pragmatic and multi-disciplinary.

Even before the term Operations Research was coined, some important contributions to this discipline were made. In 1913, Harris developed the formula for an optimal "Economic Order Quantity". Wilson (1934) promoted its use so intensively that it became known as Wilson's formula. In 1909, Erlang started his pioneering work on the theory of queues, followed by Pollaczek (1930) and Khintchine (1932). Initially, this theory was developed for solving network congestion problems. Only much later its importance was recognized for the design of service and manufacturing lines. Also, many useful statistical decision techniques, such as for statistical quality control, were developed before the Second World War (Shewhart, 1931).

When in the early 1960's the first textbooks on Production and Operations Management appeared (such as Buffa, 1961) Operations Research was enthusiastically put forward as the "scientific" side of Production Management. At that time, even knowledge of sophisticated, recently developed techniques, such as non-linear and dynamic programming was recommended and considered important for the skillful use of ordinary production systems. Obviously, the value and possible impact of Operations Research was excessively magnified. As a result, production managers gradually became very skeptical regarding mathematical techniques and this process created a kind of crisis in the Operations Research community (Ackoff, 1979).

4. The 1980's and 90's

Due to the Japanese successes in manufacturing, Western firms had to change their production practices. Nowadays, in order to survive, companies and factories must meet the international, global, competitive challenge. The result is that Production and Operations Management is receiving a lot of attention, also from universities - much more than 10 or 20 years ago.

What are the main issues of modern production management?
Roughly speaking, we can distinguish two broad streams :

1) issues that appear while extending or adapting the Japanese JIT-approach;
2) issues emerging from automation.

For example, the issue of Total Quality belongs to the first category. Total Quality Management is now attempted by almost all large companies. However, how to achieve similar successes as the Japanese firms is not clear. In Europe many companies have started to require vendors meet the ISO 9000 standards in order to obtain contracts.

Minimizing lead times or speeding up the time it takes to get new products into production are also concerns belonging to the first category. Time Based Competition, Quick Response Manufacturing (Blackburn, 1991), Supply Chain Management (Christopher, 1992), Concurrent Engineering (Halevi and Weill, 1992; Salomone, 1995), etc. are approaches that try to solve these time and flexibility issues.

Related to time management and flexibility is the problem of broadening the assortment of products, and the issue of customization, to provide the variety of choices that modern customers demand. This issue shifted the focus of Production and Operations Management to more short term planning (as defined in the framework of Anthony, 1965) and shop floor control.

Automation related issues are abundant. For example, the question of how to develop and integrate new process technologies into existing production systems. It is often difficult to effectively apply new technologies.

Along with automation and the dispersion of the personal computer, Operations Research made a successful comeback. When automation appears more decisions have to be structured and analyzed in quantitative terms and softwares have to be developed, containing specific optimization algorithms. But the quantitative, mathematical nature of Operations Research, remains an obstacle to its use and propagation. Many managers are not mathematically inclined and dislike thinking in mathematical categories. Only simulation tools are easily accepted (Warrer, 1992).

5. The Future

We would like to finish our overview of Production Management developments with a discrete attempt at making a few predictions regarding the near future.

Obviously, global competition is here to stay. The economic reforms in Eastern Europe, the economic awakening of Southeast Asia, China, India, and parts of Latin America, will accelerate and deepen this process of globalization. Worldwide production and logistics networks will develop, and these networks have to be managed. A lot of (quantitative !) planning will be needed. Also, many production managers and high-skilled workers will have to work abroad for a large part of their career. Many managers will be confronted with a diverse work force. In large firms, multiple languages and multiple cultures will become the rule rather than the exception (Kidd, 1994).

The need for firms to become and remain lean (Womack et al., 1990) will be mandatory. If required, Draconian measures, such as suggested in Business Process Re-engineering (Hammer and Champy, 1993) will be implemented to eliminate all non-value-added steps and waste. The focus will be on the entire process and not, as in the past, on a loose collection of elementary time-and-motion tasks.

Environmental constraints will become more important and will have considerable impact on logistics (Bloemhof-Ruwaard et al., 1995). New disciplines such as reverse distribution planning and product recovery management will appear. A country such as Belgium cannot continue to produce more than eight million tons of industrial waste every year. There will be a lot of work for planners and operations researchers organizing the recycling activities.

The advance of the computer, of information processing and automation will continue. But it is hard to predict the consequences. Will the factory of the future be a ghost factory with almost no workers? Most likely this will not become the rule, even in a distant future. But certainly, in most industrial branches, the number of workers is going to further decrease.

Furthermore, options and complexity will increase because of automation and well designed software, and a lot of information will be available. Technologies will reduce the constraints on what is possible. Thus workers and production managers will have to take decisions and initiatives at very short notice and on the basis of clear objectives. They will have to work as a team of very skilled persons and resume responsibility. It would no longer make sense that a few individuals at the top of the company would substantially reduce the options by imposing a set of stringent rules. Thus decentralization will become the trend. Functional divisions and hierarchies will be weakened and a more horizontal organization will emerge (Rao, 1995).

These trends are already visible in many firms; also, some service businesses and administrations are attempting changes in this direction, for example the administration of our home university, the Catholic University of Leuven. If we may believe recent newspapers, even public services and administrations in Belgium are attempting to change. Measures are taken to make these organizations less sclerotic and more customer friendly.

The three spinsters only had to deliver some specific movements with a foot, a lip or a finger. They worked next to each other, without having responsibility for the total process. But the worker of the lean, automated, agile factory of tomorrow has to

(a) be technically skilled or even multi-skilled and be prepared to re-train frequently;
(b) know enough about computers, understand the whole production flow, know the quality philosophy and rules;
(c) be able to take initiatives and responsibility, communicate well, be a good team member, speak more than one language, understand different cultures, and be very flexible.

Most likely the worker of tomorrow will have to act and collaborate along the lines of the heroes of popular TV series such as "The A-Team" or "Mission Impossible". A more realistic example would be the French organization "Doctors Without Borders". This organization provides medical support in crisis situations anywhere in the world. Teams of doctors are sent out to tackle specific assistance projects. The teams have a well defined mission and clear values. They operate in the most turbulent environments with great speed and flexibility.

The operations manager of tomorrow needs to be as well qualified as the workers. It seems that guiding real teams requires some level of introspection and a deep concern for ethical values (Welsh, 1994). A manager must be able to reflect on the team's mission and then truly motivate the other team members. This cannot be realized by financial schemes alone.

Obviously these qualifications required of workers and managers are very high and, in the future, there simply will not be enough people available meeting these high standards. Thus this type of development can only partially be realized. Society and Production Management have to find ways and means to equally employ less qualified, less resourceful persons. Yet, how remarkable this development of Production Management is. Many guidelines of modern Production

Management are almost the opposite of the recommendations made by Frederick Taylor at the beginning of this century. At that time, industry was employing an amorphous work force, undercharged in a sense, but soon industry will mainly be interested in all-round, versatile and overcharged team members.

6. Conclusions

We mainly emphasized the production aspects in this paper and much less the operations in service businesses and service in the public sector. However, it is not so that only manufacturing matters. We believe that the study of service operations is one of the most promising areas for research in the near future (Harker, 1995). There is a large scope for action and improvement since there are many service operations and many of them are plagued by low productivity.

We hope that we have made clear by means of this short overview that Production and Operations Management is indeed a functional field of business with clear line management responsibilities. It is not to be confused with the more theoretical, mathematical oriented discipline of Operations Research where decision-making tools are studied and developed that are useful for all kinds of decision making. Production and Operations Management is multi-disciplinary. It requires input of engineers, economists, operations researchers, psychologists, sociologists, and even physicians. Reflecting on its history and future, it is obvious that "the human factor" in the discipline is, and will remain, a crucial one.

The relationship between Production Management and Operations Research has been a delicate one. However, the confusions of the 1960's and 70's have been resolved and the two fields can now develop and grow while respecting their identity. Both disciplines can benefit from each other, live in close relationship, each being of service to the other.
(They married. had many children and lived happily ever after; end of the fairy tale.)

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