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Some Trends and Applications of Operational Research/Management Science to Operations Management

Ramón Companys[a] and Imma Ribas[b]

[a] Escola Politècnica Superior d'Edificació de Barcelona, UPC,
Dr. Gregori Marañón, 44-50, 08028 Barcelona
ramon.companys@upc.edu

[b] Escola Tècnica Superior d'Enginyers industrials de Barcelona, UPC.
Avda. Diagonal 647, 08028 Barcelona
imma.ribas@upc.edu

Abstract: The editor suggested us to write about our point of view on the current use of Operations Research techniques applied to the Operations Management and about its future evolution. With some of unconsciousness we accept it, but it is obvious that our vision, even though we try to do our best, will be partial and biased. Hence the title chosen shows signs of prudence. More caution have been applied to the development where, after a glance at the past and reflection on the abundance of new denominations without content, we consider five aspects that, nowadays, acquire increasing importance and that will strongly influence in future developments. Among the five aspects two correspond to trends in the field of operations research techniques, one is a philosophy in the field of operations management, another to an area of the company and the last one to an industrial sector in which operations management, supported by operations research methods, is taking a predominant role.

Key words: Operational Research, Management Science.

1. Introduction

It is impossible to try to see the present and the future without looking, occasionally, to the past. In a recent paper titled "Operational Research versus Operations Management" (Petrovic and McCarthy, 2014) published in the Operational Research Society bulletin, the connections between both disciplines are analysed. *"O. R. is as a discipline that deals with the application of advanced analytical methods to help make better decisions" whereas "OM deals with the activities, decisions and responsibilities of managing the design, production and delivery of goods and services"*. They conclude that there are many points of contact, a large area of overlap, but differ in some aspects and approaches.

For us, the concept of OR defined by Ackoff and Sasieni (1968) was and is still valid. They said that *"OR can be considered as being: The application of scientific method, by interdisciplinary teams to problems involving the control of organized (man-machine) systems so as provide solutions which best serve the purpose of the organization as a whole."*

Our only qualification is to interpret "interdisciplinary" as the existence of a team with members with different views and experiences. Therefore, for us, OR is not a toolbox, not a collection of recipes, not a profession or an academic entertainment, it is an attitude, an approach, a philosophy to focus and solve problems connected with the operation of the systems. However, we have nothing to object to the above definition of OM, although we used to distinguish, according to Buffa (1961), the strategic decisions (design) from the tactical ones (operations), and we identified OM with the latter ones.

Hence, for us, OR and OM are not the same: OR is a methodology while OM is an area of management. OR can, and probably should be, used to solve problems of OM.

If the problem is recurrent, OR will design quantitative methods and techniques that will be associated with OM. The title of this paper refers to these procedures and techniques.

For perspective we have included Figure 1. A few years ago, a graph, which appeared in the first edition of Dervitsiotis, impacted us. The graph was titled: *Chronological development of production technology (hardware) and production methodology (software)*. This figure, which originally ranged from 1750 to 1980, suggested that the development of both technology and methodology going in ascending order, with an exponential growth, but the second one, methodology, was behind technology with an apparently growing gap. A new updated version is shown in Figure 1 where the time domain is up today.

In the figure, the abscissa scale is linear and refers to the time, the ordinate scale is logarithmic and in it is measured the development in an arbitrary unit; Given the nature of the scale, the exponential growth is represented as a line segment. The upper line refers to technological development, which Dervitsiotis baptized as "hardware", and the lower, the methodological development or "software". Most milestones reflected in the figure are widely known, what excuse us of giving an explanation, which unnecessarily lengthen the text. We just indicate some details that seem significant to us.

The initial milestone, which appears in 1775, refers to the Watt's steam engine improved, contemporary with the ideas of Adam Smith on the advantages of the division of labour.

In 1798 Eli Whitney introduced the notion of interchangeability, standardization, and brought them to practice. A follower of Whitney was Colonel Samuel Colt who invented the famous revolvers, with absolutely interchangeable parts.

In 1837 general Baron Antoine Henri Jomini published *Precis de l'art de la guerre ou nouveau tableau analytique des principales combinaisons de la grande tactique et de la politique militaire*; in which what he calls the art of war is divided into six parts and the fourth one is the logistics, defined as "*practical art of moving armies.*"

Charles Babbage appears in the graph, not for designing an automatic calculating machine but for writing *"On the Economy of Machinery and Manufacturers"* (1832) that noted an advantage of the division of labor that had not been mentioned by

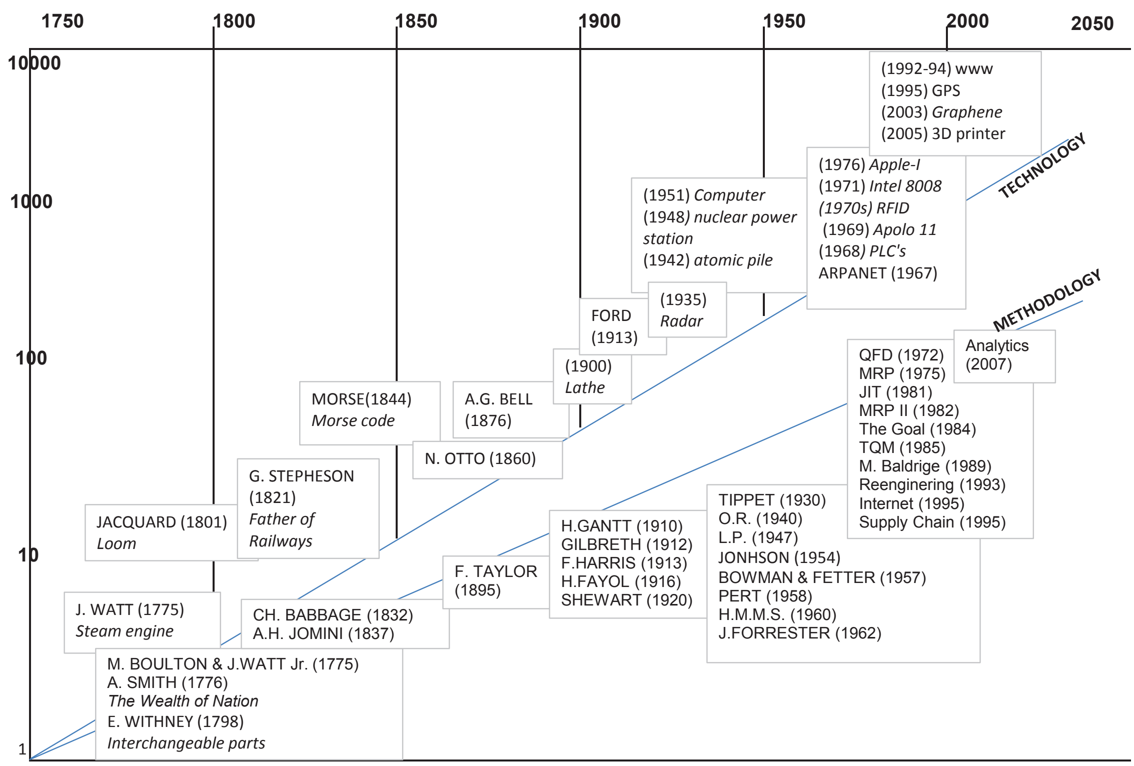

Figure 1. Chronological development of production technology and methodology.

Adam Smith. He noted that the bottleneck job was, surely, the one that perceived a higher salary, and if all the work is carried on by a single operator, he should have such category.

There is no room for stopping in F. Taylor, in Gilbreth and H. Gantt, whose contributions are widely known. Ford Harris published his formula EOQ around 1913 (although some authors situate this fact in 1911).

Less known in our environments is Henry Fayol, mining engineer of the Ecole de Saint-Etienne who entered, with 19 years old, in the Societé Commentry-Fourchambault. He published, in 1908, the report *“Discussion des Principes de l’Administration Generale”* which is the first draft of his seminal work, *“Administration Industrielle et Génerale: Prevoyance, Organisation, Commandement, Coordination, Contrôle”*, published in 1916.

In 1913, Henry Ford installed the first assembly line to produce the T Model. This is neither the first nor the only experience, but was the one that popularized the procedure, probably because it was linked to the perception of the workers of perceiving an excellent salary for those times.

Walter Shewart invented, in 1924, the Statistical Quality Control and in 1934 L. H. C. Tippet, in England, developed a new application of statistics to the production, the work sampling, accepted, albeit with great reluctance. Harold F. Dodge y Harry G. Romig, from Bell Telephone Laboratories, worked in the reception control and published their sampling tables in 1944.

The first commercially available computer, the UNIVAC I (Universal Automatic Computer) was developed by a company founded by Mauchly and Eckert, who had developed at the University of Pennsylvania the ENIAC (*Electronic Numerical Integrator and Computer*), in 1945.

Other methodological milestones include the publication, in 1957, of the book of Bowman and Fetter (1957) that was one of the first to link quantitative techniques with production management, the linear rules by Holt et al (1960), in 1960 and the models based in Industrial Dynamics by Forrester (1962).

The Advanced Research Projects Agency Network (ARPANET, 1967) was one of the world’s first operational packet switching networks, the first network to implement TCP/IP, and the progenitor of what was to become the global Internet (1995).

Although the beginnings of RFID (Radio Frequency IDentification) is around 1970 is not until 1990s when the intense use of RFID revolutionized logistics operations.

After seen the past, we can look at the present and extrapolate into the near future. A first observation we make is the feeling that the methodological innovations have been slowing since the 80s of last century. Many new names have appeared, but few new concepts. Moreover if the observations we have made on the delay of the methodology with regard the technology are true, the current technological advances, which are quite significant in the field of information systems, will be which define the methodological developments in the near future.

Three factors that, from our point of view, will influence the structure of new quantitative methods that serve as a support to operations management are: the increasing complexity of the situations they face, the risk caused by the high variability of many influential elements and the sustainability policy and respect for the environment, which is necessary in a world of limited resources. In particular, they must incorporate mechanisms to deal with two conflicting concepts: robustness to respond to the uncertainty generated by the short-term variability, and flexibility to adapt to structural changes at higher levels.

We do not know what the future will be but to discuss some connections between operations management and quantitative methods and techniques, we dealt with the following headings:

- Analytics
- Exotic heuristics
- The lean manufacturing
- The supply chain
- OR in Healthcare

2. Analytics

> *There are three kinds of lies: lies, damned lies, and statistics*. Benjamin Disraeli

> *If you torture the data long enough, it will confess.* Ronald Coase (Professor of Economics, University of Chicago)

> *You may prove anything by figures*. Thomas Carlyle, Chartism (1840)

> *If enough data is collected, anything may be proven by statistical methods*. Williams and Holland’s Law, in Arthur Bloch (1977)

Since some years ago, Analytics and Big Data have become popular, and in many cases linked to operational research environments. Possibly one of the triggers of this interest is the knowledge that, in the 2002 campaign for President of the USA, in the Obama team worked 50 experts in analytics.

One of its missions was to identify voters likely to be influenced by a contact (persuadable voters swing) and those where contact could be counterproductive. Under the orders of Chief scientist data, developed a persuasion voter model, with the following characteristics:

1. What's predicted: Which voter will be positively persuaded by political campaign contact such a call, door knock, flyer, or TV AD.
2. What's done about it: persuadable voters are contacted, and voters predicted to be adversely influenced by contact are avoided.

News in the same direction was the work of CERN to locate the theorized Higgs boson in 1964. Scientists analysed more than 800 trillion collisions to confirm their hypothesis. During this process they amassed more than 200 petabytes of data, what was scrutinized billions of times - doing statistical analysis to confirm and corroborate that the particle whose trace was found was indeed Higgs Boson. The scientists concluded that there were one-in-550 million chances that the results may have been a statistical coincidence.

What is Analytics? According to Nestler *et al.* (2012) *"Analytics is the scientific process of transforming data into insights for making better decisions"*. But also it is said *"An important aspect of teaching decision skills is the observation that we are dealing with a decision-maker, a person. People, not data, make decisions"* (Abbas, 2014).

Since old times there are two schools of thought, which according to the times and fashions are imposed on one another. One of them argue "*analyze what we do (decide) and based on this analysis we will see what data are needed"* and the other *"capture and keep all the data you can and then we will see what we do with them."*

We belong to the first one because we are of the opinion that you cannot fish smaller than the size of the fish net used. Therefore the network must adapt to the fish sought and any search results, capture and storage of data are biased by definition. Unfortunately, or fortunately, depending how you look, now the technology allows the capture, storage and processing of data on quantities and deadlines before implausible.

In the 1960s, statisticians used terms like "Data Fishing" or "Data Dredging" to refer to what they considered the bad practice of analysing data without an a-priori hypothesis. However, the term "Data Mining" that appeared around 1990 in the database community, although it is similar to the Data Fishing term became popular in the business and press communities. Since about 2007, "Predictive Analytics" (name that first appeared in 1999) and since 2011, "Data Science" were also used to describe this field.

Predictive Analytics is defined as the Technology that learns from experience (data) to predict the future behaviour of individuals in order to drive better decisions (Siegel, 2013). Millions of decisions a day determine whom to call, mail, approve, test diagnose, warn, investigate, incarcerate, set up on a date, and medicate. PA is the means to drive per-person decisions empirically, as guided by data. By answering the mountain of smaller questions PA may, in fact, answer the biggest question of all: How can improve the effectiveness of all the massive functions across government, healthcare, business, non-profit and law reinforcement work.

Continuing with the proliferation of terms to name the accumulation of data, the name Big Data, was first introduced in an article by two researchers from NASA in 1997, and is usually linked to Analytics in many contexts. We consider that Big Data refers to the capture, storage and retrieval of data and Analytics to their treatment.

Analytics has demonstrated tremendous potential to extend and improve human life by facilitating better diagnosis, promoting preventive treatment and introducing a future of personalized medicines (Rao and Jain, 2013). We assume that we should also have to talk about detection when the object of study deals with the proper functioning of a machine or a system (physical or conceptual).

Some authors claim that Big Data, accompanied by advanced analytics, enable organizations to identify meaningful materials and applicable knowledge that are buried in the data, without having to understand its reason. It is a respectable point of view, but antithetical to the scientific tradition that always asks about the why of things, what obtains, in some cases, a satisfactory answer.

How the operations research community's has welcomed Analytics? INFORS considers, almost as synonyms, Operations Research, Management Science and Analytics. ORS in the header of its newsletter writes *“INSIDE OR: The science of better at the heart of Analytics”*. In the courses given by these professional societies to train experts in Analytics appear very well known themes:

1. Define de client’s problem properly. Surfacing the “stakeholders” criteria for quality and action
2. Problem structuring and work plans. Smart decomposition of complex problems
3. Managing a project or team. Navigating client interactions. Bridging the gap between desired and available data
4. Making the case for change and implementation of the analysis and recommendations through persuasive communication. Analysing the levers of persuasion. Presenting results based on complex analytical work

That is, the same that is explained, since long time ago, as phases to follow to develop a study of OR.

Analytics and its treatment of large volumes of data open new possibilities to quantitative methods. Inspired by Mortenson *et al.* (2014) we can list some; traditionally the difficulty inherent in the models and applications of OR/MS was to have sufficient data to make the results meaningful. Currently the situation tends to become reverse and therefore models and applications should be adapted to manage large volumes of data. At the same time, the procedures to be used in hypothesis testing and validation of the models must be defined before this sea of data. The models and techniques for handling them were developed taking into account the limitations of the data. Consequently, they must be adapted (or redesigned) for the current situation.

As Ackoff (1967) indicated, it will be desirable to develop methods for reducing the data (singular value decomposition, principal components, cores or kernels) maintaining the significant insights.

Some OR / MS models are potential producers of Big Data (e.g. simulation), which until now were not utilized fully due to the difficulty of processing so condensed. Circumstances have changed; this may be subjected to a criticism review. Working with large volumes of data will be convenient to use the new data architectures, developed for this circumstance. The real-time applications can now harness the wealth of data available. The existing ones must be redesigned, and others new will be able to be designed. Moreover, in the interactive processes, it will be interesting to use intensively the display of data.

The Analytics obviously has many positive aspects, but do not hide the danger of misuse of its possibilities through a comprehensive snooping of all our acts similar to the predicted by Orwell (Orwell, 1949). However, being optimistic, we are sure that soon it will be designed and disseminated (and applied) some strategies that serve to poison the Big Brother and to get he leaves us reasonably quiet.

3. Exotic heuristics.

> *The progress of science varies inversely with the number of journals published.* Parkinson’s sixth law, in Arthur Bloch (1977)

Most of the problems found when modelling combinatorial production systems are classified as NP-hard so it is often used heuristic procedures for resolution.

RACS and RAES (Dannenbring, 1977) were two pioneering heuristics to solve flow shop scheduling problems. A first step to take was the neighbourhood definition of a given solution. In continuous functions with the solution defined as a point in a space of n dimensions, the procedure was apparently natural. In the discrete context, with the often solution described as a permutation of n elements, the things are not so clear. However, definitions of neighbourhood were found and two of the most popular were the insertion and swap ones: a transformation or movement allowed moving from one solution to another considered its neighbour and the succession of movements could identify with a path. Soon, it became obvious that, in some cases, the objective function associated with these neighbourhoods could not be considered unimodal, consequently, after some movements a better solution could be reached, but not necessarily the optimal. It was a local minimum with respect to the neighbourhood used, and it was desirable to seek ways out of this impasse. The first idea that comes to overcome this difficulty is to perform multiple searches which start in several skilfully chosen points to increase the chances of finding the global optimum. This idea leads naturally to the heuristics named MultiStart or GRASP (Feo and Resende, 1989). A natural extension is to keep the various paths in parallel with interaction between, them such as Genetic Algorithms (Holland, 1975 and Goldberg, 1989) or Ant Colony Algorithms (Dorigo, 1992)

A second idea is to provide the exploration of searching mechanisms that allow continuing the trajectory by escaping from local minima without be trapped in a circle, i.e. systematically visit the same points. This second idea has several aspects; on one hand, it leads to extensions of exhaustive descends (ED) search and non-exhaustive descends (NED) search known as Simulated Annealing (Kirkpatrick, 1983 based on Metropolis, 1953) and Tabu Search (Glover, 1986), respectively. On the other hand, to apply a random perturbation to the solution, causing a "jump" in the trajectory in order to move away (but not too much) from the local minimum, as is done in the Iterated Local Search algorithm (ILS) (Stützle, 1998) or Iterated Greedy Algorithm (IGA) (Ruiz and Stützle, 2005) and finally, since the neighbourhood structure induces that a point be a local minimum, to change the neighbourhood in order to extend the path is on another plane (Variable Neighbourhood Search (VNS) (Mladenovic and Hansen, 1999). It should not hide that several of these mechanisms can be used simultaneously.

Newer concepts have been TS, SA, GA and ACO. TS tries to avoid circuits and improve the trajectory by remembering segments, recent and not so recent, to exploit this knowledge when appropriate. It is, to some extent, imitation of human behaviour. SA is based on a metaphor from metallurgy, and presents the novelty of accepting a movement that leads to a worse solution with some probability, this probability decreases with the amount of worst solution and path length (the latter through a parameter called temperature, which decreases with time).

The basic idea of Genetic Algorithms is older, but we perceive it as a competitor of above schemes. Here the metaphor is the natural evolution. It is considered a set of solutions, called population. Each solution, called individual or chromosome, has a particular health (fitness) (corresponding to the value of the objective function), and assumes that the better health, the more positive aspects comprise the chromosome and, therefore, there is greater interest in preserving new individuals. Given two individuals, properly selected, an operator called crossover allows to generate new individuals that maintain some of the characteristics of the parents. To increase the diversity of the population another operator called mutation is introduced. This one can be identified with what we called above movement, which is applies to certain selected individuals. Finally, to keep the population within reasonable limits, a natural selection that conserves only the most promising individuals intervenes. In the ACO several agents (ants) build heuristically parallel solutions and after each shift, agents exchange information about the quality of the constructed solutions. There exists a memory that from this information or pheromone assigns a value to each of the elements likely to be part of a solution so that those who have been part of good solutions are more likely to be part of future solutions. From certain point of view, the ants learned through the common experience of the colony.

In the early 90s all these new procedures were named metaheuristics. In fact was Glover (1986) who used this name to qualify the TS. Meta is a prefix comes from the Greek μετά and that usually means, in most languages, "after" or "beyond" next to the item to which it is attached as "metaphysics", "metaphor" or " metalanguage". Hence, it was surprising to find a classification where metaheuristics are a particular category of heuristics as in Diaz and Teeng (1996). Perhaps the answer lies in the following ambiguous definition *"A metaheuristic is a high-level problem-independent algorithmic framework that provides a set of guidelines or strategies to develop heuristic optimization algorithms. That term is also used to refer a problem-specific implementation of a heuristic optimization algorithm according to the guidelines expressed in such framework"* (Sörensen and Glover, 2013). This has reminded us that over 40 years Ackoff complained that the nomenclature was not well established *"Different terms are used to refer to the same thing and the same term is used to refer to different things"* He referred to the field of systems, more than 40 years ago, but today, we could applied it to the field of metaheuristics. He concluded *"defining concepts is treated by scientist as an annoying necessity to be complete as quickly and thoughtlessly as possible. A consequence of this disinclination to define is often research carried out like surgery performed with dull instruments. The surgeon has to work harder, the patient has to suffer more, and the chances for success are decreased"*. We believe that a solution should be adopted. Otherwise everything will be qualified as metaheuristic if not as hypermetaheuristic.

Ant colonies inspired many learners of researcher. Glover and Laguna were surprised in 1977 that, given their social behavior, no one would have noticed the bees of so much literary tradition (Maeterlinck, 1901). They would have done better to leave irony to later since the bees appeared in 2005 (Karaboga, 2005), followed by flies, termites, fireflies, worms and many other insects. Once the insects were sold out, researchers were not discouraged and continued studying animal biology: kangaroos, sharks, jumping frogs and bats and even more exotic things:

intelligent water drops, cuckoo eggs and jazz. Any of these analogies allowed, with a hermetic language, presenting an algorithm labelled "new" which solved better some old problems and new ones invented for the occasion. The reasons for the explosion are many. Every guy wants to be recognized as the inventor and owner of a procedure (which provides many citations and references). If the procedure appears promising new (at least the first article about it was published) is easy to make changes that results also in publishable articles: by applying the procedure to another problem, by adding a mechanism taken from another procedure (with the which the adjective "hybrid" can be added), etc.. If the referees still swallowing, this provides more references that make the process more attractive and more attempts to use innovatively.

Sörensen (2013) has denounced the fact *"¼The behaviour of virtually any species of insects, the flow of water, musicians playing together – it seems that no idea is too far-fetched to serve as inspiration to launch yet another metaheuristic. In this paper, we will argue that this line of research is threatening to lead the area of metaheuristics away from scientific rigor¼"*. There is a very old story concerning an emperor who two clever swindlers who pose as weavers and tailors, sell a non-existent costume by convincing both the emperor and his courtiers, that the fabric was invisible to those who were in a position greater than their merits. The best known version is the tale by Andersen (1837). The story ends when the emperor wearing his supposed clothing, followed by his court makes a parade before the people and an innocent child throws the cry "the emperor has no clothes". Sörensen, like the child in Andersen's tale, has shouted "the emperor has no clothes". Will it happen as in this story?

We believe that in the near future the designers of heuristic algorithms will abandon the current tendency to use the same scheme for all problems (which favours the publication of articles and cross references that increase the impact of publications) to design heuristics "to measure", i.e. adapted to the specific problem they aim to solve and they will investigate what is the reason because certain structures and operators perform well in certain problems and less so in others. Thanks to the analytics, experimentation of various alternatives for a given algorithm will be able to find the most suitable version with credible guarantees of confidence.

A new field very promising as Sörensen indicates are the matheuristics, which tries to combine exact algorithms with heuristics. The resulting procedures generally use exact algorithms for solving subproblems that guide the behavior of heuristic algorithms, thus leveraging the best of both worlds.

On the other hand, heuristics will be developed to find solutions in real time of many situations, by establishing a proper balance between volumes of data, the complexity of the algorithm, the quality of the solution and the time available.

4. The lean manufacturing

Lean manufacturing is a production philosophy that considers the expenditure of resources in any aspect other than direct creation of value for the end customer to be wasteful, and thus a target for elimination. Therefore, the lean movement leads to highlight what adds value (which the customer is willing to pay) and ignore the rest. Lean manufacturing is a philosophy that comes mostly from the Toyota Production System (TPS).

The Japanese production systems had to be rebuilt after the war during the American occupation following occidental patterns, with support and advice of renowned specialists such nationality such as Deming and Juran, but later evolved in its original form. There are specific social characteristics of Japan and perhaps the level of automation of Japanese companies is differential, but that does not explain its high efficiency. It should be included, among these causes, not only the technical production management, especially the management of materials, but also the very concept of productive activity.

The occidental rationalism has sought a formalization of procedures that cause the Japanese industrial success (which, for some time, was considered somewhat mysterious) and this has led to the Lean Manufacturing. In a document obtained in the 80s of last century, Toyota defined the final motivation of its focus on the design and management of the production system in cost reduction by ruthless elimination of all waste (considered waste all that does not add value to the product) and the maximum use of the capabilities of operators (and not just their hands). The document added that the Toyota production system is based on two procedures: the just-in-time and jidoka. In addition, with an added conviction, belonging to the oriental culture, that fully achieve the goal marked requires a continuous improvement effort that never ends (kaizen).

Toyota distinguished 7 large groups of inefficiencies or "muda":

1. Due to overproduction.
2. Due to downtime.
3. Due to transport.
4. Due to inadequate processes.
5. Due to stocks.
6. Due to unproductive movements.
7. Due to defects in the product.

Although Lean Manufacturing is seen as an evolution of TPS to apply to other sectors and other different environments than the automotive one, some authors point out some differences, which, in our opinion, we do not seem so significant:

1. Lean focuses the emphasis on value, rather than waste. The value is produced by the manufacturer but appreciated by the customer. Lean thinking starts with a conscious attempt to define, accurately, the value in relation to specific products, with specific prices for established markets.
2. Lean identifies the value stream, i.e. the set of all actions required to go from raw material to finish product, with the concept of value from the point of view of the customer.
3. Tool orientation is a tendency in many programs to elevate mere tools (standardized work, value stream mapping, visual control, etc.) to an unhealthy status beyond their pragmatic intent. The tools are just different ways to work around certain types of problems but they do not solve them for you or always highlight the underlying cause of many types of problems. No one tool can do all of improvements.

But, despite the alleged differences, it remains valid the TPS traditional aspects such as TPM, SMED, staff participation, quality circles, etc. as it can be seen in recent articles (Shah and Ward, 2007; ElMaraghy and Deif, 2014; Chiarini, 2014)

Lean philosophy, with its emphasis on maintaining a continuous flow along what we call supply chain, instead of focusing on the nodes (plants or warehouses) in isolation, represents a necessary change in the way to raise the management in planning short and medium term, in the sizing of buffers, in scheduling, in dispatching (either with kanban or not), in monitoring, etc. This impact will gradually move to the quantitative methods and techniques that support to such management, which must be reviewed, and in some cases designed again, to which will contribute all the support provided by the Big Data, Analytics and new heuristics.

5. Supply Chain

Supply Chain was a term used by Keith Oliver, a consultant at Booz Allen Hamilton, in an interview for the Financial Times on June 4, 1982. Regardless of which were behind the name, the term took hold and, during the 1990s, appeared many papers that used it.

Oliver said in 1982: *"Supply chain management (SCM) is the process of planning, implementing, and controlling the operations of the supply chain with the purpose to satisfy customer requirements as efficiently as possible. Supply chain management spans all movement and storage of raw materials, work-in-process inventory, and finished goods from point-of-origin to point-of-consumption"*. Oliver does not properly define Supply Chain, he defines Supply Chain Management, whereas Chopra and Meindl do it in an acceptable form *"A supply chain consists of all parties involved, directly or indirectly, in fulfilling a customer request. The supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses, retailers, and customers themselves. Within each organization, such as a manufacturer, supply chain includes all functions involved on receiving and filling a customer request. These functions include, but are not limited to new product development, marketing, operations, distribution, finance and customer* service".

In any case, these definitions remind us to the definition of Logistics. Magge (1968) defined: *"Logistics is the process of monitoring and managing the flow of materials and products from its sources to its point of consumption"*. In all definitions of logistics, this is interpreted as a highly focused management activities to manage the flow of materials, but, what is the system on which the logistical management is applied? Virtually, in the same system than the supply chain management applies, i.e. in the supply chain.

Why the concept of supply chain is important? Probably, because defines the object of concern regardless of what one wants to do with it, which is the mainly difference from Logistics. Surely, we will want to govern, through effective management to pursue certain goals, but this is supplementary. We could use again Ackoff and his insistence on the importance of names and definitions.

One of the most important challenges in supply chain management is obviously the global or integrated planning, and much more difficult to perform as more organisms, with a high degree of autonomy, are present in the chain. We assume that management may not be completely centralized, because in that case the existence of the role of various organizations would have no palpable effect and the supply chain would not represent any contribution to the traditional management of production systems such as had been developed. If existing organizations in the chain have a certain degree of autonomy accompanied by some degree of power the question that is relevant is how the harmonious functioning of the whole system can be achieved in order to share, satisfactorily the obtained performance to all agents in order to motivate their collaboration. Most of the studies published so far treat this topic very partially. We believe that in the future should be deepened in some aspects related to the Theory of Games and that the equilibrium solutions will be a very interesting field to develop (see Yue and You, 2014). Moreover schemes based on the establishment of a comprehensive planning framework within which the member organizations establish their own plans harmonically must deepen and extend the traditional decompositions of Dantzig-Wolfe and Benders, or similar techniques in context of wider programming.

The three factors mentioned as guidelines for the future development of quantitative methods, which will serve as support for operations management (complexity, risk and sustainability), begin to appear in papers that revolve around the supply chain.

The supply chain is already a more complex object than the traditional production system and this complexity increases when considering the reverse logistics. The authors distinguish between three types of complexity: static, dynamic and decision-making (Serdarasan, 2013). Static (structural) complexity is associated with the structure of the supply chain, the variety of its components and strengths of interactions. Dynamic (operational) complexity is associated with the uncertainty in the SC and involves the aspects of time and randomness. Decision-making complexity is associated with the volume and nature of the information that should be considered when making a supply SC related decision. The three complexity types are interrelated, and they should not be considered in isolation.

It would be interesting to have a measure of the complexity of a system in order to evaluate the efficiency of various actions thereon. Sivadaran *et al.* (2006) uses the concept of entropy developed by Shannon (1948). A similar scheme is used by Isik (2010). With less amplitude Cheng *et al.* (2014) measure the static or structural complexity through entropy, but we consider that more important than the static concept of structural complexity is the dynamic operational complexity in which there is still a long way to go.

There are three generic approaches when dealing with complexity in the SC: complexity reduction, complexity management, and complexity prevention. This reminds us the three things that, according to Ackoff (1981), can be done with problems: *"There are three kinds of things that can be done about problems – they can be resolved, solved or dissolved. To resolve a problem is to select a course of action that yields an outcome that is good enough, that satisfices (satisfies and suffices)…To solve a problem is to select a course of action that is believed to yield the best possible outcome, that optimizes…To dissolve a problem is to change the nature, and/or the environment, of the entity in which it is imbedded so as to remove the problem. Problem dissolvers idealize rather than satisfice or optimize…"*

The steps to follow when dealing with the complexity in the SC are: to classify the complexity in necessary and unnecessary, eliminate or reduce unnecessary complexity, manage complexity and take the necessary measures to prevent the emergence of more unnecessary complexity. The use of tools based on OR / MS will be very helpful to manage the necessary complexity.

The concept of risk associated overall to the supply chain is a concept that still remains vague, ambiguous and enemy of all quantification, as concluded by the documented work by Heckmann et al (2014). One possibility would be to adapt the concept of system reliability to the SC, which continues to be a system, but the complexity of SC from the real world complicates its practical application. Therefore most authors consider the notion of risk in parts.

The policy of sustainability and environmental friendliness also is connected, as could not be otherwise, to the guidelines for the design and management of the supply chain (Winter and Knemeyer, 2013)

Both Govindan *et al.* (2013) as Brandenburg *et al.* (2014) conducted two separate analyzes of the literature from which detected some gaps that provide opportunities for research, including the interrelationship between sustainability and green in the SC, new procedures in consideration of uncertainty, multiobjective approaches etc.

6. OR in Healthcare industry

We believe that the healthcare industry is an industry where the application of the methods of OM and OR techniques has more room to go because their actual use has been, so far, rather anecdotal. In USA and UK, where there is more tradition in OM / OR, these begin to be used to provide solutions to various problems of management. Proof of this is that we recently received an issue of the Industrial Engineer journal where appears, on the back cover, an advertisement of a simulation software designed specifically to healthcare which serves to avoid risks when making decisions in an environment changing.

Perhaps the little tradition of using these techniques is due to poor knowledge that the administrators of healthcare institutions have of them and due to entry barriers for professionals belonging to other industrial sectors. However, the pressure exerted by governments on these institutions for being more efficient is forcing them to seek new ways to reduce costs and to address management problems. In this way, one of the areas where hospitals have significant opportunities for improvement is in the management of the entire supply chain, from planning to programming.

OR techniques can be used as support for both strategic and tactical decisions. In the field of strategic decisions, demand forecasting to meet the capacity requirements, decide locations to serve the greatest number of people, assess the needs of the departments by simulation or by queue models. At the tactical level, OR can help to set levels of stock of drugs, budget allocation to a set of resources, allocation of medical equipment, among others. And, for short-term decisions in the field of monitoring and control, OR allows resource scheduling, patient, operations…the reader can find a more comprehensive variety of optimization problems and the techniques used in the research being conducted in this sector by Rais and Viana (2010). But, as evidenced in Brailsford and Vissers (2011), most of the published papers are researches and models proposed that have not been implemented in the real world. According to the authors, this is due, inter alia, to *"academics need to publish in peer-reviewed journals and must therefore demonstrate theoretical or methodological advances. This tends to lead to complex, sophisticated mathematical models which can take years to develop, in stark contrast with the objective of the end-user: a simple, easy-to-use model"*.

Another area with significant opportunities is the processes improvement where the lean tools are often applied to address this problem. Implementing lean in healthcare started around 2002 and most of these projects have occurred in the USA, 57%, then the UK, 29%, followed by Australia, 4% (De Souza, 2009). These, and other lean healthcare projects have achieved some great results, for example reduction in waiting times, increased quality by reducing errors, increased employee's motivation and customer satisfaction (Radnor et al, 2012). The process improvement approach focus on three areas, first defining the value from the patient point of view, mapping value streams and create continues flow by eliminating waste (Bozena, 2010)

The main challenges in implementing lean healthcare projects are, as in other industrial sectors, getting the managers involved in the lean transformation, the lack of communication between divisions, the identification of the customer as there are many end users in health and the patient not always the one that pays for the service and the lack of understanding of lean methods within the hospitals which often results in poorly implemented lean tools and techniques in the healthcare industry.

Finally, the use of analytics in healthcare will play a great role in the healthcare system. Analytics can have numerous applications. For example, it can help to develop predictive models to forecast patient behaviour and provide preventive care, can help to compare the cost and effectiveness of interventions and treatments or can improve the response in front of disasters by having real-time data on the availability of critical resources. However, according to Ward et al (2014), some challenges need to be overcome. These include overcoming privacy concerns, collecting high quality data and making it available or developing data standards to facilitate the extraction of information from the system, among others.

7. Conclusions.

This paper tries to establish trends in the application of quantitative techniques to Operations Management. We have not been exhaustive as this would have led to a long list of problems and techniques, without sufficient space for developing them. We have chosen to focus on five aspects of different nature that we consider crucial in the current and future developments of the subject.

In the Heuristics section we noted a handicap to the true development of the subject, the complacency of the authors to establish sophisticated analogies without contributions of real value. However, we believe that the designers of heuristics will abandon the current tendency to use the same scheme for all problems to design heuristics adapted to the specific problem to deal with and that they will investigate the reason because certain structures and operators functions perform better in some problems and worse in others. Moreover, a new field very promising will be the matheuristics, which tries to combine exact algorithms with heuristics.

In Analytics we have indicated some positive aspects: the possibility of capturing, storing and processing large amounts of data that open a wide range of possibilities (next to some dangerous aspects).

In the section of Lean management, we have noted that it is a management philosophy which possibly will be a paradigm that must accommodate all aspects of operations management and therefore, the supporting quantitative tools.

With the SC concept, we have defined the system in which most of the developments of OR / MS take place and we have pointed that the most important challenge in supply chain will be the coordination between the organisms belonging to it.

Finally, to illustrate the precedent points, we include the Healthcare industry where the OM is acquiring a high degree of development.

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