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The application of Quick Response Manufacturing practices in Brazil, Europe, and the USA: An exploratory study

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ABSTRACT

This research investigates the application of Quick Response Manufacturing (QRM) practices by enterprises in Brazil, Europe, and the USA. QRM is a management concept that focuses on time as the key factor in competitive manufacturing, particularly in customer-oriented Engineer and Make to Order (ETO/MTO) production environments. A literature review identifies QRM principles, divided into four core concepts. Next, an exploratory survey in 20 manufacturing companies that operate under ETO/MTO conditions and are known to have already implemented QRM shows that: (i) the degree of the application of QRM practices is not the same for the four core concepts of QRM; (ii) the extent of the implementation of each core concept is similar among all the world regions studied; (iii) the use of Lean Manufacturing favours the adoption of QRM; and (iv) the QRM practices least applied by the surveyed organizations are those related to the abandonment of a mentality based on economies of scale and cost reduction.

1. Introduction

Time and responsiveness have become strategic factors for the competitiveness of businesses that face the challenge of competing in the dynamic and unpredictable markets of globalized trade (Stalk, 1989). Thus, flexibility and adaptability are vital factors for organizations to respond quickly enough to the demands of twenty-first-century customers, which are primarily characterized by small volume and a high variety of customized products (Suri, 2010; Jitpaiboon et al., 2016).

In the late 1980s, Stalk (1989) proposed a new paradigm for manufacturing management, called Time-Based Competition (TBC), which emphasizes the reduction of the time required for every activity related to a product or service from conception to delivery to the customer (Nahm et al., 2006). In 1998, Rajan Suri proposed the Quick Response Manufacturing (QRM) approach based on TBC. QRM is particularly suitable for manufacturing environments of low-volume and high-variety products and this approach has led to time reduction as its primary goal (Suri, 1998).

The importance of reducing lead time was initially recognized in the Toyota Production System (TPS), coined Lean Manufacturing in the occident. For the TPS, non-value added time is one of the seven types of

wastes to be removed from production processes in order to maximize the customer value and improve efficiency. However, most Lean Manufacturing implementations do not primarily focus directly on lead time reduction but instead on the well-known seven wastes (over-production, unnecessary transportation, inventory, motion, defects, over-processing and waiting) which is different from QRM where all of the improvement efforts are directed towards lead time reduction.

Although QRM has been implemented in certain companies around the world, the literature on this topic is still in its infancy stage. Currently available QRM literature mostly covers the description and development of QRM's principles, e.g., Suri (1998, 2010), case studies on its implementation, e.g., Fernandes et al. (2012), Veloso Saes and Godinho Filho (2011), and the POLCA (Paired-cell Overlapping Loops of Cards with Authorization) system implementation, e.g., Chinnet and Godinho Filho (2014), Germs and Riezebos (2010), and Vandaele et al. (2008). In a recent review of the literature on lead time reduction within the context of Time-Based Competition and QRM, Godinho Filho and Veloso Saes (2013) noted that currently available literature on practical studies of lead time reduction, particularly QRM, is quite limited. Empirical studies on the application of lead time reduction techniques organizations around the world are lacking.

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While there are many studies showing the implementation level of other modern manufacturing management approaches (e.g., Lean Manufacturing, Just in Time, Total Quality Management) around the world (e.g., White et al., 1999; Matson and Matson, 2007; Hokoma et al., 2010; Dora et al., 2014; Alcaraz et al., 2014; Bortolotti et al., 2015; Chavez et al., 2015; Vasanthakumar et al., 2016; Godinho Filho et al., 2016a; Shaaban and Darwish, 2016; Bevilacqua et al., 2015; Birkie and Trucco, 2016), the QRM literature does not present any study with such a goal.

Studies that come close to the present work are Godinho Filho et al. (2016b), Garza-Reyes et al. (2015) and Hoonte (2012). Godinho Filho et al. (2016b) conducted a survey of manufacturing companies from Brazil, Europe and the USA that operate in an Engineer To Order or Make To Order (ETO/MTO) environment and have explicitly conducted QRM journeys. These authors investigated whether these companies had full knowledge of the QRM principles or had merely applied elements (principles and tools) that have a close relationship with Lean Manufacturing. The results of the study showed that the surveyed companies had difficulty having a full knowledge of certain QRM elements, even if they were several years into QRM implementation. Additionally, these authors concluded that a mentality based on productivity, low costs and due date delivery was identified as the primary barrier for companies to achieve a higher degree of QRM knowledge. Garza-Reyes et al. (2015) explored the awareness and adoption of Lean Manufacturing (LM), Lean Six Sigma (LSS), Quick Response Manufacturing (QRM) and the Theory of Constraints (TOC) in the Greek engineering sector. An exploratory and descriptive study was conducted on 47 engineering companies in Greece. The results revealed that Greek engineering organizations were relatively unaware of the examined operations improvement approaches, and thus their implementation was very limited or non-existent at all. Hoonte (2012) performed a multiple case study on seven companies in the Netherlands, three in Norway and one in Austria, aiming to develop a model of QRM maturity that could be used by organizations as a self-assessment tool for identifying improvement opportunities. However, what is lacking in the literature is a more in-depth analysis of which elements have been successfully implemented and which elements have been neglected to see how these elements relate to the particular context in which companies operate, such as in the production environment and in terms of economic and cultural differences.

Our study aimed to investigate the degree of QRM practices implementation in companies in Brazil, Europe, and the USA and to determine whether the previous adoption of certain Lean Manufacturing elements favours QRM implementation. To the best of our knowledge, this is the first paper that try to analyse and evaluate the implementation pattern of QRM practices around the world. This is the main contribution of this paper.

The structure of the present study is as follows: Section 2 presents the theoretical framework which serves as the basis for this research; Section 3 describes the research method used and the hypotheses formulated for the study; Section 4 presents and discusses the results; and Section 5 draws conclusions.

2. Theoretical foundation and hypothesis development

Quick Response Manufacturing (Suri, 1998) stems from the Time-Based Competition paradigm and is a “enterprise-wide strategy for reducing lead time throughout the enterprise” (Suri, 2010, p.2). The most distinguishing principle of QRM is the single-minded emphasis on lead time reduction that impacts every aspect of a company. Suri (2010) argues that QRM is a complementary approach to Lean Manufacturing based on four core concepts:

- (1) The Power of Time: complete replacement of traditional cost-based goals of efficiency and utilization with QRM's primary goal of lead time reduction;

- (2) Organizational Structure: the structure of a company should support the efforts towards lead time reduction; the central objective of this change is to shift from a functional or departmental structure to a cellular structure;
- (3) Understanding and Exploiting System Dynamics: understand the relationship between the shop-floor variables that have effects on the lead time, and therefore give better guidance to the improvement efforts in these variables to maximize their effects on the reduction of lead time;
- (4) Enterprise-wide Application: Reduction of lead time should be made globally in the company. QRM is not just a shop-floor application; it must be applied to the entire supply chain, including, for example, to suppliers, office operations of sales, procurement, design, engineering, and product development.

Based on Godinho Filho et al. (2016b) and Hoonte (2012), Table 1 presents the 4 QRM core concepts and 29 QRM elements. Note that these elements are not necessarily unique to QRM, as examined by Godinho Filho et al. (2016b). However, these elements are considered essential to the QRM approach. Suri (2010) highlights that many companies working on implementing QRM face difficulties in implementing its concepts. Amongst the elements recommended by the four key concepts of QRM, certain ones involve simply applying principles and tools proposed exclusively by QRM (as is the case for POLCA) or by other modern management approaches (as is the case for manufacturing cells, cross-functional teams, employee involvement, and other issues). Finally, individual elements go beyond the simple application of the techniques and tools of QRM/Lean Manufacturing and involve a change of mentality. Examples of such principles that arise in the core concepts of #1, #3 and #4 are (i) to understand that cost reduction should not be considered the primary driver for change; (ii) to focus on lead time reduction instead of delivery punctuality; (iii) to understand that the improvement of traditional performance indicators will occur as a result of a time-focused strategy; and (iv) to understand the importance of manufacturing flexibility instead of simple maximizing the use of resources.

Our study investigates the degree of QRM practices implementation in various companies around the world, i.e., USA, Europe, and Brazil. We expected that the use of techniques and tools would be, in general, easier to implement than a change of mentality. Therefore, core concept #2 was expected to be implemented more than core concepts #1, #3 and #4. In addition, it is useful to know that all the studied companies from the USA, Europe, and Brazil had received QRM training and had been implementing QRM practices. However, only the North American companies in our data set had a long-standing relationship with the “USA QRM Center”, which was established in 1993 and is responsible for the creation and dissemination of QRM. A similar center in Europe dates only back to 2010, while in other parts of the world, including South America, no QRM center for training and supporting companies exists. Therefore, we expected that North American companies would have more training and awareness than the companies interviewed in Europe and Brazil. The present study also aimed to evaluate whether the higher degree of dissemination and training was correlated with a higher degree of implementation of QRM management practices. From these expectations, we constructed two hypotheses:

- H1. The degree of the application of the four core QRM concepts is different in the studied companies.
- H2. The degree of the application of the core concepts is different in the world regions studied.

Our study also explored whether the previous adoption of certain lean manufacturing elements favoured QRM implementation. The lean manufacturing approach systematically seeks to eliminate wastes in production systems by continuous improvement and process changes that reduce activities that do not add value to the client. This approach also encourages organizations to increase the involvement and

Table 1
QRM core concepts and elements.

Core concept 1: The Power of Time

QRM elements:

VC - Understand that the production cost should be considered a secondary indicator in relation to the lead time

VC01	Production cost is not a manufacturing management priority
VC02	Labor productivity is not a manufacturing management priority
VC03	Full capacity utilization is not one of our management priorities in manufacturing
VC04 ^a	Reducing inventory is one of our management priorities in manufacturing
VC05	We do not use cost as criterion in evaluating line managers' performance
VC06	We do not use productivity as criterion in evaluating line managers' performance

VD - Give importance to the lead time instead of delivery punctuality

VD01	We have a short delivery time
VD02	Our company does not focus its efforts on punctuality of delivery
VD03	We continuously reduce production lead time
VD04	We do not use on-time delivery as a criterion in evaluating line managers' performance
VD05	We use production cycle time as a criterion in evaluating line managers' performance

VF - Understand the importance of flexibility

VF01	We offer a large number of product features or options
VF02	We are able to quickly introduce a new product
VF03	We are able to rapidly adjust the capacity
VF04	We have the ability to make design changes

VQ - Understand that the improvement of the traditional performance indicators is a consequence of the reduction of lead time

VQ01	We deliver a high product quality performance/reliability
VQ02	We deliver a high product durability/lifetime
VQ03	We are able to solve customer complaints rapidly
VQ04 ^a	Conformance to design specifications is one of our management priorities in manufacturing

Core concept 2: Organizational Structure

QRM elements:

EOT - Multi-skilled workers

EOT01	In our organization employees receive training to perform multiple tasks
EOT02	In our organization employees are cross-trained so that they can take over tasks from other employees if necessary
EOT03 ^a	In our organization, the workers are specialized and learn to perform a few or only one job/task

EOD - Decentralized decision-making

EOD01	Our workers have the authority to correct problems when they occur
EOD02	Our work teams have control over their job
EOD03	Our supervisors or middle managers are supportive of the decisions made by our work teams
EOD04	We encourage workers to be creative in dealing with problems at work

EOY - Easy and fast internal communication

EOY01	Communications are carried out among managers frequently
EOY02	Communications are easily carried out among workers
EOY03	Strategic decisions are quickly passed on to relevant work groups
EOY04	Communication between different levels in hierarchy is easy
EOY05	Workers can easily meet and communicate with upper management

EOC - Encourage creative, autonomous work and learning

EOC01	We have written rules and procedures that show how workers can make suggestions
EOC02	Our workers have their own space and time to experiment with their job
EOC03	We have written rules and procedures that guide quality improving and creative problem-solving

EOF - Few hierarchical levels

EOF01	There are few layers in our organizational hierarchy (less than four)
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EOL - Level of horizontal integration - joint specialization

EOL01	Our tasks are done through cross-functional teams
EOL02	Our managers are assigned to lead various cross-functional teams

Core concept 3: Understanding and Exploiting System Dynamics

QRM Elements

DMCU - No maximize the use of capacity on critical resource

DMCU01	We can handle "rush orders" without disturbing our average delivery time
DMCU02	We do not aim for maximum utilization so that we gain flexibility/robustness
DMCU03	We work with a short and accurate planning horizon
DMCU04	You can buffer variability on three ways: time, capacity and inventory. Our buffers exist mainly of idle capacity, which enables us to have little till no inventory and quicker response

DMCM - Cellular manufacturing

DMCM01	Products are classified into groups with similar processing or routing requirements
DMCM02	Our processes are located close together so that material handling and part storage are minimized
DMCM03	Families of products determine our factory layout
DMCM04	Equipment is grouped to produce families of products

DMEI - Employee involvement in the product and process improvements

DMEI01	Shop-floor employees lead product/process improvement efforts
DMEI02	Shop-floor employees drive suggestion programs
DMEI03	During problem-solving sessions, we make an effort to get all team members' opinions and ideas before making a decision
DMEI04	Shop-floor employees are key to problem-solving teams

DMEX - Innovation actions to improve QRM tools

DMEX01	We created our own tools to improve lead time reductions
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DMF - Use of a hybrid control production system called POLCA

DMF01	Production at stations is "pulled" by the current demand or available capacity of the next stations
DMF02	Our production system enables us to reduce the work on the shop floor
DMF03	We use a production planning system, but only to authorize/control the first workstation of the production line

(continued on next page)

Table 1 (continued)

DMF04	We use a “pull” or combinations of “push” and “pull” production system
DMF05	Production is “pulled” by the shipment of finished goods
DMF06	Production is “pulled” by visual/virtual cards or bins
DMF07	Production at a workstation only starts when both authorizations, material, and capacity at workstation required workstations are available
DMIF - Performance feedback to the workers	
DMIF01	Charts plotting the frequency of machine breakdowns are posted on the shop floor
DMIF02	Information on quality performance is readily available to employees
DMIF03	Employees are charged by lead time rather than delivery time
DMIF04	We use fishbone type diagrams to identify causes of quality problems
DMIF05	Charts showing defect rates are posted on the shop floor
DMM - Use of TPM practices	
DMM01	We maintain all our equipment regularly
DMM02	We maintain excellent records of all equipment maintenance related activities
DMM03	We post equipment maintenance records on the shop floor for active sharing with employees
DMM04	We emphasize good preventive maintenance
DMM05	We dedicate a portion of every day to planned equipment maintenance activities
DMM06	Our operators perform certain equipment maintenance activities (such as lubricating, cleaning machine parts)
DMSP - Set-up time reduction	
DMSP01	We are working to lower set-up times in our plant
DMSP02	We reduced the set-up times of equipment in our plant to the minimum
DMSP03	Short set-up times enables us to use relative small batch sizes
DMSP04	Our crews practice set-ups to reduce the time required
DMVY - Exploitation of strategic variability	
DMVY01	We recognize strategic variability and try to exploit it
DMVY02 ^a	We eliminate bad variability out of our process
QRM core concept 4: Enterprise-wide application (Reduction of lead time globally at the supply chain)	
QRM Elements:	
EI - QRM's practices utilization on the office operations	
EID01	We are implementing actions to reduce the lead time at design department
EIE01	We are implementing actions to reduce the lead time in the engineering department
EIF01	We are implementing actions to reduce the lead time in the financial department
EIP01	We are implementing actions to reduce the lead time in the purchasing department
EIRD01	We are implementing actions to reduce the lead time in the R&D department
EIS01	We are implementing actions to reduce the lead time in the sale department
EISF - Utilization QRM practices on shop-floor	
EISF01	We are implementing improvement actions at the shop-floor driven by the lead time reduction.
EXCC - Communication with customer/user	
EXCC01	We are frequently in close contact with our clients/users
EXCC02	We strive to be highly responsive to our customers/users' needs
EXCC03	We share our forecast/demand information with the client(s)
EXCS - Communication with supplier	
EXCS01	We share our forecast/demand information with the supplier(s)
EXCS02	We frequently are in close contact with our suppliers
EXSR - Customer's feedback	
EXSR01	Our customers give us feedback about our quality and delivery performance
EXSR02	We regularly survey our customers/users' requirements
EXSR03	We encourage our customers to place frequently low volume orders
EXSR04	We have a maximum customers compliance service rate
EXSR05	Our customers experience short lead times
EXDS - Supplier's policy based on reducing lead time	
EXDS01	We receive parts from suppliers on time
EXDS02	We receive the correct number of parts from suppliers
EXDS03	We receive high-quality parts from suppliers
EXDS04	We receive the correct type of parts from suppliers
EXDS05	Our key suppliers are located in close proximity to our plants
EXDS06	We receive small-quantity frequent deliveries from our suppliers
EXDS07	We do not adopt the practice of quantum gain discount to avoid receiving infrequent large shipments
EXDS08	We train suppliers to improve lead time reduction
EXDS09	We seek to work with smaller suppliers in order to influence them towards the reduction of lead time
EXDS10	Our suppliers are aware of the power of time
EXDS11	We are aware of the supplier's lead times
EXDS12	Our suppliers have a short delivery time
EXDS13	We are able to work without stocks, due to the short delivery time(s) of our supplier(s)
EXDS14	We consider delivery time as crucial criterion in selecting suppliers
EXDS15	In some cases, we are willing to pay more for a supplier with a shorter delivery time
DPCE - Concurrent engineering (internal integration)	
DPCE01	Product development/engineering activities are parallelized (performing tasks con
DPCE02	Various disciplines are involved/integrated into product development/engineering
DPCE03	We apply tools and techniques that will shorten or integrate steps
DPCI - Customer integration	
DPCI01	We visit/listen to our clients to discuss product development/engineering issues
DPCI02	Our customers/users are actively involved in the product design process
DPCI03	Customer experience our time-to-market as quickly
DPCI04	During development/engineering, we are still able to execute customers feedback
DPCI05	We have rapid prototyping techniques

(continued on next page)

Table 1 (continued)

DPPM - Flexible development/engineering process (Project management)	
DPPM01	We use tools and techniques to cut decision-making time
DPPM02 ^a	We followed an upfront planning and phased development plan (stage-gate model)
DPPM03	Our (new) product development/engineering process is flexible so that we can quickly response to customer specific product wishes
DPPM04	During development/engineering, we have the ability to make changes, without being too disruptive
DPPM05	We measure time-to-market from the last change in requirements until the product is delivered
DPSI - Supplier integration	
DPSI01	Our suppliers develop component parts for us
DPSI02	Our suppliers are involved in the early stages of product development/engineering
DPSI03	We make use of supplier expertise in the development/engineering of our product

^a Reverse-coded item.

Source: Godinho Filho et al. (2016b).

participation of employees so that they become responsible for waste reduction (Tu et al., 2001; Shah and Ward, 2003; Yang et al., 2011). The knowledge of techniques and tools of lean manufacturing, such as value stream mapping, differentiating value-adding activities from non-value-adding activities, and problem-solving is useful to a broad set of companies and organizations. Experience with a holistic approach such as lean manufacturing might, therefore, help companies that are implementing QRM, as they have much in common. However, Garza-Reyes et al. (2015) noted that the studied companies were relatively unaware of certain modern operations improvement approaches such as QRM, and thus their implementation was very limited or non-existent. Therefore, we made the third hypothesis of the present study.

H3. The use of elements and organizational practices of lean manufacturing has the potential to help companies in their efforts towards QRM implementation.

The third hypothesis tested for support of QRM implementation by having previous experience with lean practices, but certain counter effects of having implemented lean practices may exist, such as a mentality based on productivity, low costs, and due date delivery. Such a mentality is, according to Suri (2010) and Godinho Filho et al. (2016b), generally associated with lean thinking. Suri (1998, 2010) suggested that cost thinking is the biggest obstacle in QRM implementation. Godinho Filho et al. (2016b) claimed that a mentality based on productivity, low costs and due date delivery is the primary barrier to companies achieving a higher degree of QRM knowledge. However, the view of Shah and Ward (2003) on lean as a sociotechnical system seems to contrast with such a narrow view on lean. The intention of the fourth hypothesis of the present study was to verify whether this mentality is actually present. Other obstacles could prohibit QRM practices implementation in the studied companies. Therefore, we constructed the fourth hypothesis of the present study:

H4. A mentality based on productivity, low costs and due date delivery (cost reduction mindset) is the primary driver for lack of certain QRM concepts or elements in the studied companies.

3. Research methodology and data analysis

3.1. Sample and data collection

To verify the degree of application of core QRM concepts and elements by organizations on the road to implementing QRM, a survey was conducted in 20 manufacturing companies operating with variable demand, an ETO/MTO system and small batch production in the USA, Europe, and Brazil. The unit of analysis was the manufacturing plant.

The target population for this research comprised over 200 member organizations assisted by the QRM Center at the University of Wisconsin-Madison or the QRM Center Europe, and at least fifty Brazilian companies that know/apply the QRM principles.

For Europe and North America, we selected companies that presented papers at the 2013 World QRM Conference held at the QRM Center in Madison, USA. All the organizations that made presentations at this

conference were contacted during the event. All the approached companies agreed to participate in the survey and received written instructions on how to access and complete the online questionnaire. Of all the invited companies, 12 responded to the online questionnaire: 6 US- and 6 Europe-based enterprises.

For Brazilian companies, we selected companies that already knew and applied the QRM concepts and principles. Managers of such companies attended relevant graduate courses at the Federal University of São Carlos and had already been implementing lead time reduction programmes in their companies. Among the consulted companies, 12 agreed to participate in the research and received the questionnaire by email; of these 12, 8 answered the survey. Therefore, a total of 20 companies participated in this research project.

Admittedly, the sample size used in this study was quite limited, since the target population (MTO manufacturing companies around the world that have been implementing QRM) is also relatively small. The sample size in the various regions was also affected by the companies' willingness to complete and return the questionnaire. The data analyses conducted in this research did not have the purpose of generalization, as in an exploratory study. Exploratory studies having no objective of generalization and using small samples are common in operations management literature. Some examples of papers published in the last 4 years are Srail and Ané (2016), Van Donk and Van Doorne (2015), Liu and Liang (2015), Chou (2014), and Samson and Gloet (2014).

For data collection, we used an instrument based on a questionnaire developed by Hoonte (2012) and Godinho Filho et al. (2016b) for a survey conducted in Europe in 2012 that aims to measure the degree of maturity of QRM practices in enterprises. The questionnaire was based on validated questions from literature on the adoption of Lean Manufacturing practices such as in Ward et al. (1998), Cua et al. (2001), Tu et al. (2001), Nahm et al. (2003), Ketoviki and Schroeder (2004), Koufteros et al. (2005), Li et al. (2005), and Shah and Ward (2007); this questionnaire has been tried and tested in practice (Hoonte, 2012; Godinho Filho et al., 2016b). To expand the search and apply it to companies in Brazil, the questionnaire that was originally developed in English was translated into Portuguese, following Chapman and Carter (1979).

The assessment of the degree of the application of QRM practices was conducted using a 5-point Likert scale, where 5 = completely implemented; 4 = advanced stage; 3 = partially implemented; 2 = early stage/incipient; and 1 = not implemented. Additionally, it was possible to select the option "not applicable" for every statement.

In Brazil, the survey was answered by three respondents for each company, where the respondents occupied positions as CEO or senior manager of operations, production, planning, or product engineering. In the Europe- and US-based companies, the questionnaire was answered by only one person from each organization who mostly occupied a position as CEO or senior manager of operations.

3.2. Research instrument and model of analysis

The research instrument consisted of a combination of single- and

multi-item scales to test the hypothesis formulated in this work. In the questionnaire, the four QRM core concepts are conceptualized as a set of 29 elements that represent the principles and concepts contained in each case, as shown in Table 1. For each element, a specific set of indicators corresponding to the practices related to each element was used for a total of 122 measures/indicators, also shown in Table 1.

The analysis was performed using the average and median of each element or core concept. In companies where there was more than one respondent, the median of the responses on a single item was used as the perception of the enterprise towards this item.

To compare the application degree between the elements, we used the Friedman test to construct rankings with the mean ranks arranged in decreasing order. Since the data were collected using an ordinal scale (Likert scale), we were working with nonparametric statistical tests; thus, we opted for the logical fundamentals of the Friedman test that is a nonparametric proof applicable to these situations as recommended by Siegel and Castellan Jr. (1988).

Although the Friedman test is useful for hypothesis testing when data of k corresponding samples present themselves in at least an ordinal scale, we only used it in this project to build the rankings used to compare the relative position of each QRM element/practice. This test does not use numeric data directly, but rather the positions (mean rank) occupied by the data after ordering each group separately (Siegel and Castellan Jr., 1988; Maroco, 2011), which met our need without violating any statistical assumption of normality or sample size.

Next, the Kruskal-Wallis hypothesis test was used to confirm whether the differences between the values obtained in each study region were statistically significant. The Kruskal-Wallis test is a nonparametric test used to compare three or more independent samples (Siegel and Castellan Jr., 1988; Maroco, 2011). The results of this test indicate whether there is a significant difference between at least two samples.

The test requires the following conditions be met (Siegel and Castellan Jr., 1988) for its proper use:

1. The test must be used to compare three or more independent samples;
2. The minimum size of each sample should be 6;
3. The tested data have a level measurement which is at least ordinal;
4. The data can be sorted and can be assigned jobs or orders; and
5. The test cannot be used to test differences in a single sample measuring respondents more than once.

We worked with three independent samples (Brazil, Europe, and the USA) with $n = 8$, $n = 6$ and $n = 6$, respectively and the data were on an ordinal scale and liable to be sorted in orders with respondents (companies) measured once in each indicator; thus, we can say that the assumptions for the use of the Kruskal-Wallis test were met.

In all tests, the software used was SPSS 20, with a significance level of 5%.

4. Results and discussions

4.1. Comparing the degree of application of QRM core concepts

The degree of the application of core concepts was estimated by calculating the average and the median of the elements of each core

Table 3

Results of comparison of QRM's core concepts application degree by region.

Core concept	The Power of Time	Organizational Structure	Dynamic System	Wide company application
Chi-square	3470	4618	2981	2498
Freedom degree	2	2	2	2
<i>p-value</i>	0,176	0099	0,225	0287

concept using the overall sample with no stratification. Aiming to compare the application degree of core concepts, we designed a ranking system with the median and sorted in descending order, as shown in Table 2. We then performed the Kruskal-Wallis test to verify if there were statistically significant differences between the assessed regions.

In the ranking shown in Table 2, the core concept “the power of time” is the least applied whereas the core concept “organizational structure” is the most used. This discrepancy provides evidence to support hypothesis H1 of the present study. This can also be seen in the results of Kruskal-Wallis hypothesis test shown in Table 3, in that there are no statistically significant differences. Thus, the results are valid for all of the studied regions, which does not support hypothesis H2 of the present study.

4.2. Comparing the degree of application of QRM elements

As highlighted in Section 3.2, the 29 QRM elements are conceptualized as sub-dimensions of the core concepts, and the QRM implementation degrees were measured by calculating the median of an appropriate set of indicators consisting of 122 practices regarding each element as shown in Table 1.

The four core QRM concepts encompass a series of elements as shown in Table 4. The analysis in the following section sought to identify the most and least applied QRM elements by QRM companies and to verify whether the found significant differences depended on the region in which the companies were located.

4.2.1. Identification of QRM elements most and least applied

To identify the QRM elements most and least applied, we present the elements' application degree ranking with the mean rank values obtained in the statistical Friedman test, with the elements listed on a decreasing scale as shown in Table 4. Next, we conducted the hypothesis testing of Kruskal-Wallis.

Table 4 shows the relative position of each element in the application ranking. In this table, the six (20%) elements most applied by companies (hatched in grey) are in the beginning part of the scale, and the six (20%) elements least applied elements (hatched in grey), are in the final part of the scale.

Amongst the six elements most used by the surveyed companies, none belonged to the core concept #01 “Power of Time”. On the other hand, amongst the set of six least applied elements, three (50%) belonged to the core concept #1. For example, elements VC (“understand that cost should be considered a secondary performance indicator in relation to the lead time”) and VQ (“understand that the improvement of traditional indicators is a consequence of a time-based strategy”) occupied the last positions on the application ranking in the three regions studied. Again,

Table 2

Ranking of the degree of application concerning QRM's core concepts.

Core concept	BRA		EURO		USA		Overall Sample			
	Average	Median	Average	Median	Average	Median	Average	Median	^a Mean Rank	Ranking
Organizational Structure	3,88	4,00	3,33	3,75	4,33	4,00	3,85	4,00	3,28	1,00
Dynamic System	3,31	3,00	3,17	3,50	4,00	4,00	3,48	4,00	2,58	2,00
Wide company application	3,50	3,50	2,92	2,75	3,75	4,00	3,40	3,50	2,45	3,00
The Power of Time	2,38	2,00	2,83	3,00	3,00	3,00	2,70	3,00	1,70	4,00

^a Friedman Test ($N = 20$; $\chi^2 = 22,200$; $gl = 3$; $p = 0,000$).

Table 4
Ranking of the degree of application concerning QRM's elements.

Core concept	Code	Element	BRA		EURO		USA		Overall Sample			
			Average	Median	Average	Median	Average	Median	Average	Median	^a Mean Rank	Rating
2	EOY	Easy and fast internal communication	4,06	4,00	3,67	4,00	4,50	4,50	4,08	4,00	20,95	1
4	EXCS	Communication with supplier	3,94	4,00	3,33	4,00	4,50	4,50	3,93	4,00	19,55	2
2	EOD	Decentralized decision-making	3,84	4,00	3,42	4,00	4,17	4,00	3,81	4,00	19,00	3
4	EISF	Utilization QRM practices on shop-floor	3,75	4,00	3,67	4,00	4,33	4,50	3,90	4,00	18,95	4
4	EXCC	Communication with customer/user	4,25	4,50	3,25	3,75	3,83	4,00	3,83	4,00	18,30	5
2	EOF	Few hierarchical levels	2,94	3,00	4,00	4,50	4,17	4,50	3,63	4,00	17,75	6
2	EOL	Level of horizontal integration - joint specialization	3,66	3,50	3,33	3,75	4,08	4,00	3,69	4,00	17,73	7
1	VF	Understand the importance of flexibility	3,69	3,50	3,67	4,00	3,75	4,00	3,70	4,00	17,30	8
2	EOT	Multi-skilled workers	3,63	4,00	3,17	3,50	4,17	4,00	3,65	4,00	17,00	9
3	DMF	Use of a hybrid control production system called POLCA	3,63	4,00	3,58	4,00	3,67	4,00	3,63	4,00	16,75	10
4	DPCI	Customer integration	4,19	4,75	2,92	2,75	3,58	4,00	3,63	4,00	16,68	11
4	EXSR	Customer's feedback	4,06	4,00	2,75	2,75	3,83	4,00	3,60	4,00	16,48	12
3	DMEX	Innovation actions to improve QRM tools	3,31	3,00	3,67	3,50	3,50	3,50	3,48	3,00	15,98	13
3	DMIF	Performance feedback to the workers	3,50	3,75	3,08	3,50	3,83	4,00	3,48	4,00	15,50	14
3	DMCM	Cellular manufacturing	3,47	3,38	3,33	3,75	3,58	4,00	3,46	3,88	15,38	15
3	DMM	Use of TPM practices	3,59	3,88	3,25	3,50	3,58	3,50	3,49	3,88	15,18	16
3	DMCU	No maximize the use of capacity on critical resource	3,28	3,00	3,50	3,50	3,50	3,75	3,41	3,13	14,80	17
4	DPCE	Concurrent engineering (internal integration)	3,50	3,50	2,75	2,25	4,00	4,00	3,43	3,75	14,50	18
4	DPPM	Flexible development/ engineering process	3,44	3,50	2,67	2,00	4,00	4,00	3,38	3,50	14,33	19
2	EOC	Encourage creative, autonomous work and learning	3,63	4,00	2,67	2,00	3,83	4,00	3,40	4,00	14,23	20
3	DMSP	Set-up time reduction	3,19	3,00	3,00	3,00	3,92	4,00	3,35	3,50	13,68	21
3	DMEI	Employee involvement in the product and process improvements	3,25	3,50	2,67	2,25	3,92	4,00	3,28	3,50	13,28	22
4	EIOF	QRM's practices utilization on the office operations	3,44	3,25	2,92	3,00	3,33	3,50	3,25	3,00	12,70	23
3	DMVY	Exploitation of strategic variability	3,31	3,25	3,25	3,50	3,58	4,00	3,38	3,50	12,50	24
4	DPSI	Supplier integration	3,63	3,75	2,33	2,00	3,50	4,00	3,20	3,25	12,20	25
1	VD	Give importance to the lead time instead of delivery punctuality	2,94	3,00	3,00	3,00	3,50	3,50	3,13	3,00	11,33	26
4	EXDS	Supplier's policy based on reducing lead time	3,00	3,00	2,33	2,00	3,17	3,00	2,85	3,00	9,05	27
1	VC	Understand that the production cost should be considered a secondary indicator in relation to the lead time	2,13	2,00	2,58	2,25	2,67	2,75	2,43	2,00	8,05	28
1	VQ	Understand that the improvement of the traditional performance indicators is a consequence of the reduction of lead time.	1,53	1,12	2,25	2,00	2,00	2,00	1,89	2,00	5,93	29

^a Friedman Test (N = 20; $\chi^2 = 109,244$; df = 28; p = 0,000).

all of these results show the difference in the applicability of the elements of the four concepts, providing support for the hypothesis H1 of the present study.

The reason for the low application of the key concept “the power of time” probably stems from the fact that lead time was not yet seen as the primary performance indicator in the surveyed companies, but is essential to the QRM approach. This concept is, therefore, a point to be improved in the surveyed companies.

Companies have a greater difficulty in applying the practices relating to the power of time because these practices involve the abandonment of the paradigm of competition based on productivity and cost. The latter paradigm is still deeply rooted in the mentality of production managers that apply or have applied practices from mass production. In fact, this mentality was found in several companies of the studied sample that now seek also to reduce time.

The results shown in Table 4 also demonstrate that 50% (3 of 6) of elements of the core concept #02 “Organizational Structure” related to lean and other approaches were among the most applied (Top 6) elements.

Meanwhile, 50% (3 of 6) of the elements of the core concept #01 “the power of time” accompanied by the element DMVY, the “Exploitation of Strategic Variability”, appeared among the least applied (Bottom 6) elements. These results once again confirm those obtained in 4.1.

The result concerning core concept #2 probably occurred because the QRM recommendations regarding organizational structure (manufacturing cells, teamwork, autonomy and empowerment, reduction of hierarchical levels, and multi-functionality among others) have close similarities to Lean Manufacturing, which is already quite widespread and implemented in companies around the world. Therefore, hypothesis H3 of the present study is supported by the data.

The element EISF “utilization of QRM practices to reduce lead time in the shop-floor” was among the Top 6, while the element EIOF “using QRM practices to reduce lead time in the office” appeared just above the Bottom 6. These results show that the QRM practice is still very tied to production areas and still lack the understanding that it can and should be expanded to all areas of the company. Moreover, certain elements that characterize QRM specifically, for example, DMCU “does not maximize

Table 5
Results of Kruskal-Wallis hypothesis test.

Rating	Code	Element	Medians			Results of Kruskal-Wallis test			
			BRA	EURO	USA	χ^2	fd	p-value	Conclusion about observed differences
1	EOY	Easy and fast internal communication	4,00	4,00	4,50	3,569	2	0,168	Statistically insignificant
2	EXCS	Communication with supplier	4,00	4,00	4,50	5,254	2	0,072	Statistically insignificant
3	EOD	Decentralized decision-making	4,00	4,00	4,00	2,295	2	0,318	Statistically insignificant
4	EISF	Utilization QRM practices on shop-floor	4,00	4,00	4,50	2,366	2	0,306	Statistically insignificant
5	EXCC	Communication with customer/user	4,50	3,75	4,00	4,251	2	0,119	Statistically insignificant
6	EOF	Few hierarchical levels	3,00	4,50	4,50	3,853	2	0,146	Statistically insignificant
⋮									
24	DMVY	Exploitation of strategic variability	3,25	3,50	4,00	1,475	2	0,478	Statistically insignificant
25	DPSI	Supplier integration	3,75	2,00	4,00	5,879	2	0,053	Statistically insignificant
26	VD	Give importance to the lead time instead of delivery punctuality	3,00	3,00	3,50	2,15	2	0,341	Statistically insignificant
28	EXDS	Supplier's policy based on reducing lead time	3,00	2,00	3,00	4,866	2	0,088	Statistically insignificant
29	VC	Understand that the production cost should be considered a secondary indicator in relation to the lead time	2,00	2,25	2,75	1,879	2	0,391	Statistically insignificant
28	VQ	Understand that the improvement of the traditional performance indicators is a consequence of the reduction of lead time	1,12	2,00	2,00	3,173	2	0,205	Statistically insignificant

the use of capacity on critical resources” and DMF “makes use of a hybrid control production system called POLCA”, are being applied by the companies surveyed, which shows that they know the basis of QRM.

4.2.2. Comparing the degree of application concerning QRM elements in the different world regions studied

The Kruskal-Wallis hypothesis test was conducted to verify whether the differences between the median values of the most and least applied elements were statistically significant among the studied regions. Table 5 shows the Kruskal-Wallis test results for each Top 6 and Bottom 6 elements in the overall application degree ranking.

The results of Kruskal-Wallis hypotheses test show that there was no statistically significant (p-value < 0.05) difference between the studied regions for any of the investigated elements, again yielding no support for hypothesis H2 of the present study. The results are valid for the three studied regions, although there was a marginal difference in the element “Integration with Suppliers” (p-value = 0.053), for which it was observed that the degree of the application by the European sample of companies

was lower compared to companies of the other studied regions.

4.3. Comparing the degree of application concerning QRM practices

Aiming to capture the multiple aspects of the QRM implementation process, the analysis in this section seeks to identify the most and least applied practices by companies in each assessed region and to verify whether there were remarkable differences between the regions.

To compare the degree of the application of QRM practices, we first identified and ranked the practices per region. The mean rank values obtained from the statistical Friedman test are listed on a decreasing scale in Tables 6–8. We also present the results of the Kruskal-Wallis hypothesis test.

4.3.1. Assessment of the application of QRM practices by companies in Brazil

Table 6 shows the top and bottom 12 QRM practices implemented for companies in Brazil. In the set of the twelve (10%) practices most applied

Table 6
Ranking of top 12 and bottom 12 QRM practices implemented in Brazil.

Core concept	Code	Practices (measurements items)	Average	Median	Mean Rank	Rating
1	VF01	We offer a large number of product features or options	4,63	5,00	103,00	1
2	EOY01	Communications are carried out among managers frequently	4,50	4,50	103,00	1
3	DMCM01	Products are classified into groups with similar processing or routing requirements	4,38	5,00	98,38	3
4	EXCC02	We strive to be highly responsive to our customers/users' needs	4,44	4,75	95,50	4
4	EXCC01	We are frequently in close contact with our customers/users	4,31	4,75	92,56	5
3	DPCI01	We visit/listen to our customers to discuss product development/engineering issues	4,31	5,00	90,94	6
2	EOD04	We encourage workers to be creative in dealing with problems at work	4,13	4,50	89,19	7
3	DPCI04	During development/engineering, we are still able to execute customers feedback	4,25	4,25	88,94	8
4	EXDS04	We receive the correct type of parts from suppliers	4,19	4,00	88,06	9
2	EOD02	Our work teams have control over their job	4,00	4,00	87,56	10
4	EXSR01	Our customers give us feedback about our quality and delivery performance	4,19	4,75	87,50	11
3	DMF02	Our production system enables us to reduce the work on the shop floor	4,19	4,75	87,25	12
⋮						
1	VC06	We do not use productivity as criterion in evaluating line managers' performance	2,13	2,00	29,94	111
3	DMCU04	You can buffer variability on three ways: time, capacity and inventory. Our buffers exist mainly of idle capacity, which enables us to have little till no inventory and quicker response	2,31	2,25	29,69	112
1	VD02	Our company does not focus its efforts on punctuality of delivery	2,00	2,00	28,88	113
1	VC05	We do not use cost as criterion in evaluating line managers' performance	1,88	1,50	25,06	114
1	VD04	We do not use on-time delivery as a criterion in evaluating line managers' performance	1,75	1,00	24,69	115
1	VC02	Labor productivity is not is not a manufacturing management priority.	1,88	2,00	24,38	116
1	VC01	Production cost is not is not a manufacturing management priority.	1,94	2,00	23,81	117
1	VQ02	Our company has greater efforts focused on reducing lead time than producing high durability/lifetime products	1,50	1,00	17,94	118
4	EXDS02	We receive the correct number of parts from suppliers	1,81	2,00	17,81	119
1	VQ04	Conformance to design specifications is one of our management priorities in manufacturing	1,38	1,00	16,44	120
1	VQ01	Our company has greater efforts focused on reducing lead time than producing high quality and reliability products	1,31	1,00	15,63	121
4	EXDS13	We are able to work without stocks, due to the short delivery time(s) of our supplier(s)	1,75	1,50	14,25	122

Table 7

Ranking of top 12 and bottom 12 QRM practices implemented in Europe.

Core concept	Code	Practices (measurements items)	Average	Median	Mean Rank	Rating
3	DMF01	Production at stations is “pulled” by the current demand or available capacity of the next stations	4,00	4,00	96,25	1
2	EOF01	There are few levels in our organizational hierarchy (less than four)	4,00	4,50	96,08	2
3	DMM01	We maintain all our equipment regularly	4,00	4,00	93,50	3
2	EOD01	Our workers have the authority to correct problems when they occur	4,00	4,00	92,42	4
3	DMCU03	We work with a short and accurate planning horizon	3,75	3,50	92,17	5
1	VQ03	We are able to solve customer complaints rapidly	3,83	4,00	92,00	6
1	VD03	We continuously reduce production lead time	3,83	4,00	90,42	7
3	DMVY01	We recognize strategic variability and try to exploit it	3,83	4,00	89,33	8
2	EOY01	Communications are carried out among managers frequently	3,83	4,00	88,92	9
1	VF01	We offer a large number of product features or options	4,00	4,00	88,83	10
4	EXCC02	We strive to be highly responsive to our customers/users' needs	3,83	4,00	88,42	11
3	DMCM01	Products are classified into groups with similar processing or routing requirements	4,00	4,00	88,33	12
						:
3	DMF06	Production is “pulled” by visual/virtual cards or bins	2,00	1,50	38,50	111
4	EXDS13	We are able to work without stocks, due to the short delivery time(s) of our supplier(s)	2,17	2,00	37,83	112
1	VC02	Labor productivity is not is not a manufacturing management priority.	2,17	2,00	37,67	113
4	EXSR02	We regularly survey our customers/users' requirements	2,33	2,00	37,58	114
4	DPCI05	We have rapid prototyping techniques	2,17	2,00	37,42	115
4	EXDS10	Our suppliers are aware of the power of time	2,17	2,00	35,58	116
3	DMEI02	Shop-floor employees drive suggestion programs	2,17	2,00	33,50	117
1	VQ02	Our company has greater efforts focused on reducing lead time than producing high durability/lifetime products	2,00	2,00	32,33	118
4	DPPM01	We use tools and techniques to cut decision-making time	2,17	2,00	31,92	119
1	VD02	Our company does not focus its efforts on punctuality of delivery	1,67	2,00	26,17	120
4	EXDS08	We train suppliers to improve lead time reduction	1,83	2,00	23,67	121
1	VQ01	Our company has greater efforts focused on reducing lead time than producing high quality and reliability products	1,50	1,50	20,17	122

Table 8

Ranking of top 12 and bottom 12 QRM practices implemented in USA.

Core concept	Code	Practices (measurements items)	Average	Median	Mean Rank	Rating
2	EOY05	Workers can easily meet and communicate with upper management	4,83	5,00	103,25	1
2	EOD02	Our work teams have control over their job	4,67	5,00	96,75	2
3	DMIF02	Information on quality performance is readily available to employees	4,50	4,50	96,67	3
2	EOY02	Communications are easily carried out among workers	4,50	4,50	92,50	4
4	EXCC01	We are frequently in close contact with our customers/users	4,50	4,50	92,33	5
4	EXCS02	We frequently are in close contact with our suppliers	4,50	4,50	92,33	5
2	EOD01	Our workers have the authority to correct problems when they occur	4,33	4,00	88,67	7
3	DMM01	We maintain all our equipment regularly	4,33	4,00	88,67	7
4	EXDS04	We receive the correct type of parts from suppliers	4,33	4,00	87,83	9
3	DMEI04	Shop-floor employees are key to problem-solving teams	4,33	4,50	87,75	10
3	DMCM02	Our processes are located close together so that material handling and part storage are minimized	4,33	4,50	87,42	11
2	EOY01	Communications are carried out among managers frequently	4,33	4,50	86,50	12
4	EISF01	We are implementing actions for improvement at the shop-floor driven by the lead time reduction.	4,33	4,50	86,50	12
						:
4	EXDS08	We train suppliers to improve lead time reduction	2,33	2,00	26,58	111
4	EXDS10	Our suppliers are aware of the power of time	2,50	2,50	26,08	112
4	EXDS07	We do not adopt the practice of quantum gain discount to avoid receiving infrequent shipping of large quantities	2,25	2,25	23,50	113
1	VC01	Production cost is not is not a manufacturing management priority.	2,00	2,00	21,67	114
4	EXDS01	We receive parts from suppliers on time	2,00	2,00	21,67	114
1	VQ01	Our company has greater efforts focused on reducing lead time than producing high quality and reliability products	1,83	2,00	21,33	116
2	EOT03	In our organization, the workers are specialized and learn to perform a few or only one job/task.	1,83	1,50	20,25	117
3	DMIF03	Employees are charged by lead time rather than delivery time	1,83	2,00	17,25	118
4	EXDS02	We receive the correct number of parts from suppliers	1,83	2,00	17,08	119
1	VD04	We do not use on-time delivery as a criterion in evaluating line managers' performance	1,67	1,50	15,67	120
1	VQ02	Our company has greater efforts focused on reducing lead time than producing high durability/lifetime products	1,50	1,00	15,67	120
1	VD02	Our company does not focus its efforts on punctuality of delivery	1,33	1,00	7,42	122

by companies in Brazil, one practice (VF01, production flexibility) belonged to the construct “the power of time.” Five practices (EXCC01, EXCC02, DPCI01, EXSR01, DPCI04) focused on support and/or integration with customers; one practice (EXDS04) concerned the quality and integration of suppliers and four practices (EOY01, EOD04, EOD02, DMF02) aimed at teamwork and reducing waste. From the group of 12 QRM practices least applied by companies in Brazil, nine practices (VQ01, VQ02, VQ04, VC01, VC02, VC05, VC06, VD02, VD04) concerned the core concept #01 “the power of time”. These results show that the QRM practices that fight against the mindset based on productivity and cost reduction were not popular among the companies surveyed in this region. Lead time reduction was not seen as the primary focus of management nor a primary performance measure of production, as demonstrated by the low use of practices related to the power of time concept.

4.3.2. Assessment of the application of QRM practices by companies in Europe

Table 7 shows the top and bottom 12 QRM practices implemented for companies in Europe. The majority of practices in the top 10% belonged to the core concepts “organizational structure” (EOD01, EOF01, EOY01) and “systems dynamics” (DMF01, DMM01, DMCM01). Note that these practices have significant similarities with lean manufacturing practices. It is worth highlighting the presence of practices VQ03, EXCC02, DMVY01 and DMCU03 among the most used ones. These practices increase responsiveness and recognize and seek to exploit strategic variability, which are key points in QRM.

Among the 12 practices least applied by enterprises surveyed in Europe, four practices (VC02, VQ02, VD02, VQ01) focused on reducing lead time, confirming previous insights that companies have greater difficulty in applying practices that use lead time as the primary metric of production performance. Another three of the least applied practices (EXDS08, EXDS10, EXDS13) belonged to the core concept #04, which advocates that the dissemination of QRM practices should extend throughout the supply chain. These results show that for European companies, QRM practices were not being disseminated to suppliers.

4.3.3. Assessment of the application of QRM practices by companies in the USA

Table 8 shows the top and bottom 12 QRM practices implemented for companies in the USA. The majority of practices in the top 10% belonged to core concepts #2 “Organizational Structure” (EOY05, EOD02, EOY02, EOD01, EOY01) and #3 “system dynamics” (DMIF02, DMM01, DMEI04, DMCM02). This result is similar to what we found in European companies and might be explained by the fact that the implementation of these concepts requires more training and awareness and that the QRM centres in these regions provide such training.

It is worth highlighting the presence of the practices EXCC01 and EXCS02 “integration with suppliers” and “integration with customers”, and the practice EISF01 “utilization of QRM on the shop-floor” among the most used ones. In addition to the internal implementation, companies in the USA seek to expand QRM to their customers and suppliers.

The set of 12 practices least applied in USA companies comprises four practices (VC01, VD04, VQ01, VQ02) concerning the use of lead time as the primary measure of performance and a primary focus on manufacturing management, three practices (EXDS07, EXDS08, EXDS10) on the reduction of lead time of suppliers and two practices (VD02, DMIF03) relating specifically to focusing on lead time instead of delivery punctuality.

5. Conclusions

This paper aimed to investigate the extent of the application of QRM practices by enterprises in Brazil, Europe, and the USA. In the literature review, very few studies were found on the degree of QRM implementation by companies.

The present study first compared the application degree of core

concepts using a ranking with the median ordered on a decreasing scale. The results show that there are differences amongst the application degree of the core concepts. Core concept #1, the “power of time”, was the least applied by the surveyed companies, while the most applied was core concept #2, “Organizational Structure”. The results of the Kruskal-Wallis hypothesis test show that the above results are valid for all three regions. Thus, hypothesis H1 (degree of application of the four core QRM concepts is different in the studied companies) was supported by the data, while hypothesis H2 (degree of application of the core concepts is different among the studied world regions) was not supported. These results have clear, practical implications for managers. Although the results did not identify any tendency by world regions studied, it is clear that companies are choosing different paths to implement QRM. These paths are not necessarily equal to the basics steps suggested by Suri (2010, 1998), what indicates that there is no a one best way to implement QRM in practice. These different paths are likely being chosen according to company characteristics and the difficulties that they are facing during the implementation process. Actually, these results are according to Godinho Filho and Veloso Saes (2013), who claims that the essential aspect of the QRM is the relentless focus on lead time reduction and not on specific tools and methods. Therefore, managers in practice should be prepared to customize the QRM implementation according to their company's characteristics.

The present study also evaluated the degree of application of QRM elements (seen as a sub-dimension of the core concepts) using a ranking showing the relative position of each element according to its implementation degree ordered on a decreasing scale. None of the six elements most applied by companies belonged to the core concept #1 “the power of time”, while three elements of this core concept belonged to the set of the six elements least applied by the surveyed companies. This result confirms that the practices of the elements of the “power of time” are the least applied and shows that lead time has not yet been adopted as the primary performance indicator by the surveyed companies, although this is a fundamental aspect of QRM.

It could also be observed that most of the implemented practices belonged to the core concept #2 “organizational structure”. These QRM practices, such as manufacturing cells, empowerment, teamwork, and the reduction of hierarchical levels, hold significant similarities with lean manufacturing. Therefore, H3 (The use of elements and organizational practices of Lean Manufacturing has the potential to contribute to companies' efforts towards QRM implementation) is supported by the data. This result is an important academic contribution of the study, as it clearly shows that certain elements of Lean Manufacturing can form the basis for the implementation of QRM approach. Therefore, the present study provides support for the majority of literature which compares QRM and Lean and see both as complementary approaches (for example Mourtzis and Doukas, 2014; Manzouri and Ab Rahman, 2013; Stump and Badurdeen, 2012; Suri, 2010) and raise doubts about the literature which present both as separate approaches (for example Powell and Strandhagen, 2012; Gunasekaran and Ngai, 2012; Corbett and Campbell-Hunt, 2002).

We also identified the practices most and least applied in each region. The most applied practices in Brazil are those that focus on support/integration with customers and suppliers belonging to the core concept #4 “enterprise-wide application”. The possible reason for this regional result was that the majority (7 of 8) of the companies of the sample in Brazil are big companies that have a large influence on their supply chain.

Among the companies surveyed in Europe and the USA, the majority of the most applied practices belonged to core concepts #2 “organizational structure” and #3 “system dynamics”. Practices that focus on Organizational Structure are rather similar to traditional Lean Manufacturing practices. Practices focusing on System Dynamics require specific training as they are rather distinctive from Lean Manufacturing. These practices require specific knowledge to use simulation software, optimization, and scheduling features among others, which are primarily

provided by training courses. The QRM centres in Europe and the USA do provide such training on these subjects, while Brazil lacks such a QRM center.

The majority of practices least applied belonged to the core concept #1 “the power of time”. We observed that a mentality based on productivity and cost reduction was still very entrenched in these QRM companies, a fact that was observed in all the surveyed regions. Therefore, Hypothesis H4 (A mentality based on productivity, low costs and due date delivery, i.e., the cost reduction mindset is the primary driver for the studied companies not having implemented certain exclusive QRM concepts or elements) was supported by the data.

Finally, the results of the present study indicate that the most important barrier for companies implementing the QRM approach was to change from cost-based competition to time-based competition. This finding is relevant for managers who are trying to implement QRM in their operations. Although Suri (2010) has already suggested this finding, only with the current study has it been shown with empirical data.

As researched companies must meet the requirements of knowing QRM and being involved in implementing actions to reduce lead time, the target population was small, and contact was not so easily performed. From these, results a major limitation of the present study: the sample size. The sample size used in the present study was relatively small, which can originate bias. However, in the present study this limitation was contemplated, once the main purpose of our research was exploratory. According to Forza (2009), sample size in exploratory studies should be just sufficient to include the range of the interest phenomena and the representativeness of such sample is not a criterion, once the generalization is not the main goal. The bias was also minimized by the use of nonparametric statistical techniques, which are appropriate for samples with these characteristics (Forza, 2009, pp. 147). Another limitation of the present study was the fact that only in Brazil was the questionnaire filled out by multiple respondents in each company. In the other surveyed regions, only one professional from each company replied to the questionnaire.

Some avenues for future research arise from this paper. One could be study the effect of cultural differences in the implementation of the QRM practices, specially those related with human resource management. This issue is studied concerning lean manufacturing literature (for example Danese et al., 2017; Boscari et al., 2016), but not within QRM approach. Other possible study would be to form a partnership with QRM Center in order to perform a larger survey.

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