PERFORMANCE METRICS IN MANUFACTURING ENVIRONMENTS IN BRAZIL: From Significant Correlations to Contrary-Significations

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ABSTRACT

This article aims to present the significant correlations between evaluation metrics and AMT's (Advanced Manufacturing Technologies), resulting from a national survey among the 500 largest industrial companies of Brazil. The sample was composed of 21 companies, whose participation was recorded through an electronic form previously tested. We used Spearman's rank Correlation Test for (i) metrics of productivity, quality and flexibility, and (ii) AMT's (1 level and 2). Inferential data analysis showed significant moderate correlations, strong and very high between AMT's at the same level (software-software; hardware-hardware) and between AMT's at different level (hardware-software). There were also negative correlations of moderate significance, strong and very high for the 03 types of metrics. The confirmation of the hypothesis allows the conclusion that the evaluation metrics of manufacture should be aligned to the operational purposes of AMT's, legitimizing them use and validity.

Keywords: *metrics; performance metrics; advanced manufacturing*

1. PROBLEM AND CONTEXT

Advanced Manufacturing (MA) is a designation for plants in which technologies, process and management are in the orbit of technological innovation and respond efficiently and effectively to the imminent and unforeseen contingencies and management issues of manufacturability. These problems are almost always associated with performance issues, whether physical production resources (productivity) or non-physical or organizational resources (flexibility and quality).

The modular configuration of a MA plant involves resources and equipment (hardware, robotics and mechatronics) and intangible assets (software, norms, standards and methods) that are designed (originally) and which remain active under the impact of technological innovation and, therefore, able to respond to issues of organizational performance and competitiveness of their structures. In this sense, the control and alignment of the resources are in the focus of industrial management, demanding monitoring activities, measurement, tweaks and updates. Industrial intelligence is formatted to track system performance and model evaluation and improvement solutions, focused on previously programmed results.

Organizational assessment focus has been performance dimensions that go beyond the tangible nature of manufacturing operations, including vectors associated with human capital, organizational and technological knowledge for which there is a lack of methodologies for identification, tracing and metrification. According to strategic models, productivity measures are relevant analysis information, and can be used both during

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evaluation phase of intra and extra-enterprise environments as in formulation of competitive strategies, being allocated, respectively, to company internal environment analysis and to organizational goals and targets definition (Kotler & Keller, 2006).

Recent studies show that it is necessary to pay equal attention to both instrumental and behavioral dimensions in a performance management system. An appropriate combination of those dimensions leads to better benchmarking of competitive performance (Wall, 2010). Therefore, organizational performance evaluation linked to organization competitive strategies can reflect company achieved results more effectively, besides aiding in the creation of a successful results based organizational culture.

Specialized literature has aroused an important discussion on the strategies of organizational management and production companies, pointing out all those instruments as significant factors for performance in productivity. According to vector approach Severiano Filho (1999), the emerging concepts of this new strategic order, translated by trade-offs of high relevance in productivity, quality and flexibility are the main features of the so-called *Advanced Manufacturing Technologies*-AMT's.

The organizational performance of an MA environment should reflect the intrinsic characteristics of technologies that are configured so that an integrated approach for its measurement involves produmetry, qualimetry and fleximetry parameters. Such parameters are almost always absent in classical performance evaluation methodologies, because they involve tangible and intangible aspects of the new settings. In this regard, qualitative models for measuring organizational performance involving human capital and intangible assets have contributed greatly to a more accurate assessment and fine performance of the company as a whole (Kaplan & Norton, 1992), (Edvinsson & Mallone, 1998), (Sveiby, 2000), (Probst, Raub & Romhardt, 2002).

Research trends in the field of organizational performance metrification point out to integrated assessment modeling of various assets involved in production (human, organizational, physical and technological), as well as the joints of these competitive strategies adopted by companies. According to Pereira (2003), competitiveness and performance are intrinsically related to each other as performance evaluation is the manner in which the organization verifies the effectiveness of their strategic decisions, which in turn influence competitiveness of organizations or systems.

A proper understanding of measurement logic and its respective metrics imposes itself as the central question in evaluation of organizational performance, especially in production environments that are configured under the aegis of AMT's. Thus being, the objective of this article is to present the main correlations between evaluations metrics in advanced manufacturing environments, in parallel to the contra-significations of the performance measures identified in an investigation carried out in the brazilian industrial sector.

2. MATERIAL AND METHOD

From theoretical viewpoint, this survey is based on concepts of organizational performance, advanced manufacturing and competitive strategy and it was accomplished in 05 (five) operating procedures, organized according to the nature of work and methodological principles of the scientific research process, so as to grant attainment of the objectives proposed.

The population investigated was set based on an appointment held by 1000 Value Magazine published in the Valor Econômico Newspaper (2011). The note ranked the 500 largest manufacturers of Brazil, listed in order of net revenues. Of this universe, it was used both random type and probabilistic sample, which amounted 165 companies from different activity sectors.

Research variables were converted into items and these in data, composing a survey questionnaire (both electronic and manual version) with 101 items, arranged in 04 classes of variables: deployed technology programs; organizational and technological components of the productive process; process performance metrics; company's competitive strategy. Pilot tests were applied in 03 big manufactures (Indaiá, Elizabeth Ceramics and GSM), that were not included in the sample.

Taking pilot tests as basis, a new form was, then, prepared, which was tested by two academics of the manufacturing field, by an industrial consultant and by one academic from research methodology field. The electronic form was forwarded to research subjects (Executive Manager), previously identified and accredited (via website-contact) to join the research. In the sequence the manual version of the form was forwarded by mail merge, in the same order of submission of the respondents stated.

Data collection process, by those two ways, resulted in a composition of 21 questionnaires answered, being 13 by electronic means and 08 by direct mail. The respondent organizations, here called "laboratory etnocases", stand for various branches of activity, including metallurgy and steelmaking, oil and gas, sugar and alcohol, textile, chemical, food and beverage, construction and engineering, fertilizers and cellulose. Completed forms were stored in a database (EC2M Data System-postdoctoral research), getting a statistical treatment (descriptive and inferential) from SPSS. The test was the Spearman correlation, with analyses based on (Bryman & Cramer, 2003).

3. RESULTS, DISCUSSION AND CONTRIBUTIONS

3.1 Technological Characterization of Surveyed Companies

The national survey named "organizational Performance of the Consolidated Experience of Advanced Manufacture in Brazil – Metric Modeling" was recorded by 21 (twenty-one) companies from different industrial sectors, all included and very well positioned in the ranking of the 500 largest manufacturers in Brazil (www.valor.com.br). The investigated companies make extensive use of advanced manufacturing technologies, both software nature (AMT-N1) and hardware type (AMT-N2) as shown in Tables 1 and 2.

The software nature of AMT's defines the technologies contained in the management of production processes and are translated by methods, procedures, norms, principles and tools, with applications in operations management. In turn, the AMT's hardware natures are all technologies that use machine language and who offer contributions in carrying out production operations (manufacturing and services).

Research findings show that both types of technologies (AMT-N1 and N2-AMT), as the implementation of these (between 01 and 05 and over 05 years), vary linearly between the surveyed companies, as well as among the industries to which they belong. In the theoretical understanding of this article, the technologies deployed between 01 and 05 years reveal a state of technological emergence in the organization, with demands for monitoring and attention from administrators and users. On the other hand, technologies deployed for more than five years show a consolidation and maturity status in an organization that holds governance and control of deployment results or even of results potentially expected.

In the category of AMT-N1, it was found that the CAD technology leads the use in respondent companies (94.7%), presenting itself as the resource with the longer maturity, since about 80% of them indicated it had been was implanted for over five years. In this same order of consideration (great use and significant implantation time) are ABC technology and CAQ (68.5% and 57.9%, respectively); ISO (73.7% and 57.9%); MRP (94.3% and 63.2%); TQC (73.7% and 68.4%); EDI (63.2% and 47.4%), according to data presented in Table 1.

Table 1. Types of AMT's and Time to Value in Companies

Advanced Manufacturing Technologies	Typology	1 – 5 years	+ 5 years
ABC (Activity-Based Costing)	AMT-N1	10,6	57,9
BSC (Balanced Score Card)	AMT-N1	21,7	38,9
CAD (Computer Aided Design)	AMT-N1	15,8	78,9
CAQ (Computer Aided Quality)	AMT-N1	10,6	57,9
EAV (Value Analysis and Engineering)	AMT-N1	10,5	47,4
EDI (Electronic Data Interchange)	AMT-N1	15,8	47,4
ISO (International Standards Organization)	AMT-N1	15,8	57,9
JIT (Just-in-Time)	AMT-N1	10,6	31,6
KANBAN (Production Control Cards)	AMT-N1	11,8	23,5
MFV (Value Flow Map)	AMT-N1	15,8	31,6
MRP (Material Requirements Planning)	AMT-N1	31,1	63,2
MRP II (Manufacturing Resources Planning)	AMT-N1	11,1	50,0
PFA (Flow Analysis Pulled)	AMT-N1	15,9	47,4
SGHST (Management System in Occupational Safety and Hygiene)	AMT-N1	5,3	73,7
STP (Toyota Production System)	AMT-N1	11,2	22,2
MTP (Total Predictive Maintenance)	AMT-N1	30,1	36,8
TQC (Total Quality Control)	AMT-N1	5,3	68,4
TRF (Quick Change Tools)	AMT-N1	16,7	11,1

Source: Direct Search, 2012.

Searched companies also include AMT-N2-type technologies in their production, as Table 2 shows. In this case, 57.9% of CAE technology, with 47.4% recorded significant maturity (over 05 years) in use of the resource. In this sequence, there have been significant use assignments to CAM technologies (52.6%), CIM (52.6%), FMS (36.9%), CNC (31.6%), FMC (31.6%), NC (31.6%) and MC (27.8%).

Table 2. Types of AMT's and Time to Value in Companies

Advanced Manufacturing Technologies	Typology	1 – 5 years	+5 years
CAE (Computer Aided Engineering)	AMT-N2	10,5	47,4
CAM (Computer-Aided Manufacturing)	AMT-N2	-	52,6
CIM (Computer-Integrated Manufacturing)	AMT-N2	15,8	36,8
CNC (Computerized Numerical Control)	AMT-N2	-	31,6
FMC (Flexible Manufacturing Cell)	AMT-N2	5,3	26,3
FMS (Flexible Manufacturing System)	AMT-N2	10,6	26,3
MC (Cellular Manufacturing)	AMT-N2	5,6	22,2
NC (Numerical Control)	AMT-N2	5,3	26,3

Source: Direct Search, 2012

It is known that a manufacturing environment is configured from a portfolio of AMT's, either of software or hardware nature. This technological configuration, in turn, should have a direct and intimate combination (best link) among resources components, so that the strategic goals of the organization are achieved. In this research, it was found that the AMT's deployed by companies have, in general, 03 significant correlations types: *significant Correlations at the same level: AMT-N1 with AMT-N1*; Significant *correlations at the same level: AMT-N2 with AMT-N2*; and *Significant correlations between different levels: AMT-N1 with AMT-N2*.

3.2 Significant Correlations between Technologies in use in Companies

According to the inferential data analysis, Table 3 presents significant correlations at the same level for the AMT's 1 level in companies (N = 21) searched. From data collected and based in Bryman and Cramer (2003), it appears that: TQC and SGHST technologies, employed by 73.7% and 79%, respectively, of the population investigated, showed a very high correlation, suggesting that industrial plants with fully controlled quality require, in parallel, a management system in occupational safety and hygiene that give support to the company quality policy.

In the sequence, the JIT and KANBAN, technologies employed by 42.2% and 35.3%, respectively, of the surveyed companies, registered a significant correlation considered strong. With the same significant correlation considered strong, appeared EDI technologies and PFA, used by 63% of businesses, and ABC and EDI, used by 68.5% and 63.2%, respectively, of the units surveyed. These findings confirm the hypothesis that there is integration possible and mutually-reinforcing characteristics between the AMT's, and that it is this combination that guarantees the results and performances that are potentially assigned to them.

Table 3. Significant Correlations of the Advanced Manufacturing Technologies Level 1

Variables	Correlation (rho)	Sig. (ρ)	N
ABC → CAD	0,485	0,026	21
→ EAV	0,479	0,028	21
→ EDI	0,703	0,000	21
→ MFV	0,449	0,041	21
→ PFA	0,598	0,004	21
CAD → EAV	0,495	0,022	21
→ EDI	0,563	0,008	21
CAM → EDI	0,533	0,013	21
→ PFA	0,556	0,019	21
CAQ → MRP	0,443	0,044	21

EDI → MRPII	0,448	0,042	21
→ PFA	0,731	0,000	21
ISO → SGHST	0,626	0,002	21
→ TQC	0,514	0,017	21
JIT → KANBAN	0,784	0,000	21
→ MFV	0,649	0,001	21
→ PFA	0,548	0,010	21
→ STP	0,677	0,001	21
KANBAN → MFV	0,673	0,001	21
→ STP	0,615	0,003	21
→ TPM	0,448	0,042	21
→ TRF	0,606	0,004	21
MFV → PFA	0,510	0,018	21
→ TRF	0,571	0,007	21
MRP → MRP II	0,460	0,036	21
MRP II → PFA	0,506	0,019	21
→ STP	0,443	0,044	21
PFA → TPM	0,572	0,079	21
→ TQC	0,503	0,020	21
→ TRF	0,476	0,029	21
STP → TRF	0,444	0,044	21
TQC → SGHST	0,873	0,000	21

Source: Direct Search, 2012.

Inferential analysis in collected data also pointed significant moderate level correlations for a number of technologies (AMT-N1), with highlights for the correlations identified among: JIT and STP, employed by 42.2% and 33.4%, respectively, of the surveyed companies; KANBAN and MFV, used by 35.3% and 47.4, respectively; JIT and MFV, in 42.2 percent and 47.4 percent, respectively, of the cases; ISO and SGHST in 73.7% and 79%, respectively; KANBAN and STP, 35.3% and 33.4%, respectively; KANBAN and TRF in 35.3% and 27.8%, respectively.

The study also points out significant correlations between the AMT-N2 (hardware level) as shown in table 4. That category revealed strongly significant correlations between CAE and CIM technologies and CAE and CAM used by 57.9% and 52.6% of companies, respectively. There were also registered significant correlation between FMC and FMS, at 31.6% and 36.9% of the population, and even between CNC and NC, which were employed by 31.6% of cases investigated.

Table 4. Significant correlations of the Advanced Manufacturing Technologies of Level 2

Variables	**Correlation (rho)**	**Sig. (ρ)**	**N**
CAE→ CAM	0,750	0,000	21
→ CIM	0,826	0,000	21
CAM → CIM	0,722	0,000	21
→ CNC	0,539	0,012	21
CNC → FMC	0,528	0,014	21
→ NC	0,838	0,000	21
FMC → FMS	0,748	0,000	21
→ MC	0,596	0,004	21
→ NC	0,574	0,007	21

Source: Direct Search, 2012

Inferential analysis also pointed out significant moderate level correlations between the AMT-L2 in the following compositions: CAM and CNC, used by 52.6 and 31.6% of companies respectively; CNC and FMC, employed by 31.6% of the population; FMC and MC, used by 31.6% and 27.8%, respectively, between FMC and NC, also used in 31.6% of the investigated cases. Those significant correlations confirm the hypothesis that

AMT's hardware level overlaps architectures designed for manufacturing environments in which modeling is almost always based on the concepts of system flexibility and integration.

The two different types (AMT-AMT-N1 and N2) gather resources that necessarily complement each other for designing and modeling advanced production architectures. This hypothesis is confirmed by the significant identified correlations between the different levels (hardware and software) of AMT's, as expressed in Table 5. According to data, there are significant correlations between AMT's different levels used by the companies investigated, in the following order of notes:
Concering moderate significance level, there were identified positive correlations in absolute majority of the technologies used, suggesting that software and hardware features present different degrees of dependency. Still, linear needs of AMT's combined (level 1 and 2) are linked to the requirements of integration and flexibility of production processes and management.

Table 5. Significant correlations of the Advanced Manufacturing Technologies between Different Levels

Variables	Correlation (rho)	Sig. (ρ)	N
ABC → CAE	0,445	0,043	21
→ CAM	0,677	0,001	21
→ CIM	0,437	0,048	21
→ CNC	0,652	0,001	21
→ FMC	0,499	0,021	21
→ FMS	0,436	0,048	21
→ NC	0,494	0,023	21
CAD → CAM	0,527	0,014	21
CAE →CAD	0,458	0,037	21
→ EAV	0,567	0,007	21
CAM → CAQ	0,598	0,004	21
CAQ → CAE	0,569	0,007	21
→ CIM	0,616	0,003	21
CNC → CAD	0,563	0,008	21
→ EAV	0,484	0,026	21
→ EDI	0,483	0,027	21
EDI →CAM	0,533	0,013	21
→ FMS	0,489	0,025	21
→ FMC	0,549	0,010	21
→ NC	0,540	0,012	21
FMC → JIT	0,578	0,006	21
→ KANBAN	0,536	0,012	21
→ MFV	0,689	0,001	21
→ PFA	0,706	0,000	21
→ TPM	0,507	0,19	21
→ TRF	0,542	0,011	21
FMS →JIT	0,538	0,012	21
→ KANBAN	0,504	0,020	21
→ MFV	0,641	0,002	21
→ PFA	0,641	0,002	21
→ TPM	0,579	0,006	21
→ TRF	0,692	0,001	21
JIT→ MC	0,527	0,014	21
KANBAN → MC	0,699	0,000	21
MC → MFV	0,434	0,049	21
→ STP	0,544	0,011	21
→ TPM	0,440	0,046	21
→ TRF	0,659	0,001	21
NC → PFA	0,547	0,010	21
→ STP	0,434	0,049	21
→ TQC	0,439	0,046	21
TPM → CIM	0,524	0,015	21

Source: Direct Search, 2012

A significant positive correlation was identified between FMC Technologies and PFA, used by 31.6% and 63.3% of the surveyed companies. These findings confirm the hypothesis that the flexible manufacturing cells operate linear streams of pulling production nature, adopting management schemes focused and closely monitored.

3.3 Organizational Performance Evaluation Metrics of AMT's in Business.

In this research, the evaluation of organizational performance was held in 03 manufacture dimensions of assessment, namely: productivity of physical resources; elaborate manufacturing quality; and flexibility of the production system. In each of the dimensions obtained significant markers of metrics used by the companies surveyed, as well as their respective frequencies of calculation, as can be seen from figures given in Table 6.

In what concerns to productivity measures of physical resources in the companies investigated, the following observation notes: (a) the production per hour-man (PHH) is measured in 68.4% of the companies, with daily and monthly measuring frequency; (b) the production by the working section (PST) is measured in 78.9% of the participating companies, 47.4% of these do it daily; (c) the total production of the workforce (PTMO) is measured in 63.2% of the investigated cases, with fortnightly, monthly end weekly measurements frequency.

Table 6. Frequency of Calculation of Production Metrics with Significant Correlations.

Metrics	Code	Distributed Frequency (%)	Total (%)
Production per Hour-Man	PHH	36,8 (D); 31,6 (M)	68,4
Production per Worker Section	PST	47,4 (D); 5,3 (S); 26,3 (M)	78,9
Total Production of the Workforce	PTMO	21,1 (S); 10,5 (Q); 31,6 (M)	63,2
Rate of Defective Products	TPD	52,6 (D); 5,3 (S); 26,3 (M)	84,2
Scrap rate	TR	57,9 (D); 21,1 (M)	78,9
Index of Rejection	IR	47,4 (D); 26,3 (M)	73,7
Customer Complaint Rate	TRC	31,6 (D); 5,3 (Q); 36,8 (M)	73,7
Index of Absenteeism	IA	15,8 (D); 5,3 (S); 63,2 (M)	84,2
Idle Rate	TO	15,8 (D); 5,3 (S); 31,6 (M)	52,6
Factory Underutilization Rate	TS	21,1 (D); 10,5 (S); 36,8 (M)	68,4
Average time of Hours Charts	TP	36,8 (D); 10,5 (S); 5,3 (Q); 31,6 (M)	84,2
Inventory Rotation Index	IR	21,1 (D); 15,8 (S); 42,1 (M)	78,9
Average Time of Manufacture	TF	36,8 (D); 5,3 (S); 31,6 (M)	73,7

Source: Direct Search, 2012.

As to manufacture quality measures, it was noted that 84.2 percent of companies measure the Rate of Defective Products (TPD), 52.6% of them do so on a daily basis; the Waste Rate (TR) is measured by 78.9% of companies, with daily and monthly measurements frequency; the Rejection Rate is measured by 73.7% of companies, assuming daily and monthly measurements.

For the measures of flexibility of the production system operated by the companies, it´s possible do make the following observations: Manpower Absenteeism Index (IA) and Mean-Time-to-Time Charts (TP) are measured by 84.2% of enterprises with distributed measurement frequencies between daily, weekly, biweekly and monthly; the Idle Rate of Labor (TO) is measured by 52.6% of companies, with daily, weekly, and monthly measurements; the Factory Underutilization Rate (TS) is checked in 68.4% of the cases surveyed, with measuring frequencies ranging between daily, weekly and monthly; the Stocks Rotation Rate (IR) is verified by 78.9% of companies, with 42.1% of them do so on a monthly basis; the Average Manufacturing Time (TF) is measured in 73.7% of the companies, with measuring frequencies ranging between daily, weekly and monthly.

The nature and types of performance measurements of a production system should reflect its architecture and its modus operandi. This is because the measurement shall promote an authentic and consistent assessment of the entity, regarding its relevance and essentialities. Under that perspective, many performance measures considered "classic" lose importance and meanings in manufacturing environments. To meet the goals of understanding performance measurements, this research investigated the correlations between the performance metrics and the AMT's responsible for re-setting of the production systems.

Inferential data analysis about productivity metrics of physical production resources evidenced, as Table 7 shows, moderate and strong significance negative correlations between 03 metrics and 06 types of AMT 's,

levels 1 and 2, with the following assignments: the metric of PHH, measured by 68.4% of all companies, presents negative correlation of medium significance with CAE and CIM technologies; the metric of PST by 78.9 percent of companies studied, shows negative correlation of moderate significance with ABC technology; the PTMO, metric employed in 63.2% of companies, has strong significance of negative correlation with CAE and CIM technologies and of moderate significance with CAQ, CAM and TPM.

Table 7. Significant Correlations of System Productivity Metrics

AMT's	PHH ((rho); (ρ); N	PST (rho); (ρ); N	PTMO (rho); (ρ); N
ABC		-0,495; 0,043; 17	
CAQ			-0,579; 0,030; 14
CAE	-0,669; 0,006; 15		-0,726; 0,003; 14
CAM			-0,644; 0,013; 14
CIM	-0,645; 0,009; 15		-,0803; 0,001; 14
TPM			-,0573; 0,032; 14

Source: Direct Search, 2012

PHH Production per hour-man;
PST Production per section;
PTMO Total production of the workforce;

These results confirm the hypothesis that productivity measures based on manpower have little or no meaning for the interests of measuring manufacturing environments. The reason is because in those environments, the intensity of human resource use is very low or none at all, characterizing it as a labor non-dependent organization. With respect to manufacturing quality measures drawn up by participants of this research, the inferential data examination consigned moderate significance of negative correlations between 04 metrics and 08 types of AMT's, levels 1 and 2, as set out in Table 8.

Table 8. Significant Correlations of Quality System Metrics

AMT's	TPD (rho); (ρ); N	TR (rho); (ρ); N	IR; (rho) ; (ρ); N	IRC ; (rho) ; (ρ); N
CAQ			-0,651; 0,006; 16	
EAV	-0,528; 0,024; 18			
FMS		-0,503; 0,039; 17		
MRP		-0,509; 0,037; 17		
PFA		-0,529; 0,029; 17		
TQC		-0,514; 0,035; 17		
SGHST	-0,494; 0,037; 18	-0,649; 0,005; 17		
TPM				-0,555; 0,026; 16

Source: Direct Search, 2012.

TPD Rate of Defective Products;
TR Scrap Rate;
IR Index of Rejection;
TRC Customer Complaint Rate.

The significance of moderate negative correlations have been identified between the metric of TPD and EAV and SGHST technologies; between the metric of TR and the FMS technologies, MRP, PFA, TQC and SGHST; between the measure IR and CAQ technology; and between the metric of TRC and TPM technology. These results confirm the hypothesis that the joint use of AMT's makes quality measurements irrelevant and/or secondary, once the AMT's own intrinsic principle as the "zero defect".

For the flexibility of metrics in the production systems operated by the companies investigated, inferential analysis indicated significant moderate negative correlations, strong and very high among 06 metrics and 12 types of AMT's, levels 1 and 2, as set out in Table 9. In this dimension, the significance of moderate negative correlations have been identified between the IA and the CAE, CIM technologies, CAM, FMC, FMS, PFA and TPM; between the metric from TO and the CIM technologies, EAV and EDI; between the metrics of TS and the CAD, CAE and CAM technologies; between the metrics of TP and ABC technologies, PFA and TQC; among the measures of IR and the PFA and CAM technologies; and the measures of TF and CAE technologies, CAM and PFA.

Considering that absenteeism, idleness, underutilization, hours charts, stocks totation and manufacturing time represent important aspects of human intervention on a production system, and that the significant correlations for these measures are of a negative nature (moderate), we have the confirmation of the hypothesis that these measures do not have grip or realism with the AMT's that configure manufacturing environments investigated.

Table 9. Significant Correlations of the Metrics System Flexibility.

IA (rho) (ρ) N	TO (rho) (ρ) N	TS (rho) (ρ) N	TP (rho) (ρ) N	IR (rho) (ρ) N	TF (rho) (ρ) N
CAE	CAE	CAD	ABC	CAM	ABC
-0,575	-0,767	-0,581	-0,563	-0,530	-0,770
0,013	0,010	0,037	0,015	0,029	0,001
18	10	13	18	17	15
CAM	CAM	CAE	PFA	PFA	CAE
-0,479	-0,797	-0,569	-0,580	-0,580	-0,603
0,044	0,006	0,043	0,012	0,012	0,017
18	10	13	18	18	15
CIM	CIM	CAM	TQC		CAM
-0,522	-0,633	-0,616	-0,490		-0,553
0,026	0,050	0,025	0,039		0,032
18	10	13	18		15
FMC	EAV	CIM			PFA
-0,535	-0,691	-0,908			-0,580
0,022	0,027	0,000			0,012
18	10	13			18
FMS	EDI	EAV			
-0,501	-0,635	-0,908			
0,034	0,049	0,000			
18	10	13			
PFA	TPM				
-0,525	-0,753				
0,025	0,012				
18	10				
TPM					
-0,692					
0,001					
18					

Source: Direct Search, 2012.

IA Index of Absenteeism;
TO Idle Rate;
TS Under-Utilisation Rate;
TP Average time of hours Charts;
IR Inventory Rotation Index;
TF Average Time Manufacturing.

Even in that dimension were identified strong significance negative correlations between metrics TO and CAE technologies, CAM and TPM; and between TF measures and ABC technology. Also, there were identified very high significance of negative correlations between metrics of TS and CIM technologies and EAV.

The strong negative correlations significance identified for measurement of idleness explain the assumption that, in environments of AMT 's, resource use is lean, feeding small and regular production lots, evidencing idleness

as something irrelevant for purposes of measurement. Data shown pointed in tables 9, 10 and 11 suggest the invalidation of metrics due to different levels of significance for negative correlations. These finding points to a situation of innocuous measurements, indicating flaws in designs of performance measurement systems operated by the companies surveyed.

4. CONCLUSIONS

The surveyed companies have technological maturity in the integrated use of AMT's, operating different configurations of tools in two levels of design (hardware and software). Independent of industrial branch, deployment and management of AMT's meet the specific needs of flexibility and integration of production systems incorporated to manufacturing plants, not having been identified cases of isolated experiments with one or two AMT's in particular. This conclusion is based on the positive correlations of meaning moderate, high and very high among AMT '-N1 and AMT's-N2.

Measures for manufacture assessment are based both in features and equipment and in intangible production, favoring the productivity of physical resources, emphasizing manufacturing quality and flexibility of the production system. The metrics used belong to different schools, going from classical to alternatives and including conventional indicators (as per hour-man, for example) and unconventional (as the average lead time, for example).

In the scope of the technical measurements and taking as a basis the inferential analysis, it is concluded that at least 03 metrics (PHH, PST and PTMO) present inverse relevance with the AMT's employed by the companies. The same inferential analysis, also concludes that quality metrics called by TPD, TR, BR and TRC flexibility and metrics measured by TO, TS, TP, IR and TF do not specify value measurement systems evaluation of environments surveyed since they are negatively correlated to the AMT's used. One of the metrics of flexibility we see, however, that IA and TP are the most frequent measures (N = 18) among the companies studied, clearly contradicting the economy criterion for the choice of the indicators that should compose the systems of measurements.

Research findings lead to conclusive inference that performance metrics that are contra-significant with respect to the AMT's used by the manufacturing system should not be included in the composition of measures around the performance measurement system. Thus, a performance evaluation architecture based on productivity, quality and flexibility of manufacture should be aligned to the goals of measurement that are consigned to their metrics, observing the degree of positive correlations of these with the AMT's incorporated by the production system.

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