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BENEFITS OF LEAN MANAGEMENT: RESULTS FROM SOME INDUSTRIAL CASES IN PORTUGAL

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ABSTRACT: *This paper documents a set of Industrial Lean projects over a decade timespan in the North of Portugal, which were conducted by final year students of the Integrated Master Course on Industrial Management and Engineering (IME) in partnership with the Department of Production and Systems of University of Minho. The study analyses a total of forty one such projects and reveals a clear growth in the number of Lean projects, and gives some evidence of Lean awareness and importance to companies. The lean tools used were listed and the most frequently applied tools spotted. Resulting benefits to companies were documented and quantification of such benefits endorsed. Results from 2010 indicate a strong growth in the ratio of quantification of benefits, but the remaining data does not clearly support such trend.*

1. INTRODUCTION

A recent survey to the Portuguese industry argues that the inability to quantify benefits could be one of the obstacles to widespread implementation of lean practices (Silva et al., 2010). According to such study, managers are reluctant to adopt new production paradigms if the expected benefits are unclear or if there is no prompt way to measure those benefits. Although the benefits of Lean have been thoroughly documented in technical books and scientific publications in the four past decades, at industrial level decision making is essentially grounded on economic reasoning and judgement, namely on perceived risk associated to such decisions and on the return on investment. The main purposes of this paper are: (i) study Lean projects implementation patterns within industry, (ii) identification of the most used lean tools and (iii) identification and quantification of benefits. The work is based on the analysis of a set of Lean projects in industry from 2001 to 2010, developed in Portuguese companies.

This paper is organized in five sections. Section 1 introduced the relevance of the work reported on the present study and its main objectives. Section 2 presents a literature review on Lean production, its main lines of reasoning and tools. Section 3 presents a number of industrial projects which endorsed specific Lean aspects. Section 4 conducts the analysis and discussion of results from the set of industrial cases previously typified. Finally, some conclusions are drawn on the last chapter.

2. LITERATURE REVIEW

The designation "lean production" was coined by John Krafcik, one of the researchers involved in a five years study (1986-1990) of the world automobile industry described in the book "The machine that changed the world" (Womack et al., 1990). Lean production is just the western designation of the Toyota Production System (TPS) whose development started at the Toyota Motor Company after the end of the Second World War (Ohno, 1988; Monden, 1988; Shingo, 1989). The referred best-seller book reveals the TPS benefits when compared with mass or craft production. According to Sugimori et al. (1977) the TPS exhibited, when it was first introduced, two main distinctive features: (i) Just-in-time production; (ii) Empowerment of workers. TPS attempted to cut production costs by removing all forms of waste that were naturally incorporated, while looking for solutions to technical and organizational challenges within shop-floor activities. But the true spirit of TPS goes well beyond that, since it nourishes from steady continuous refinement of the processes themselves. Continuous improvement of processes require two preconditions: (i) workers are entrusted and liable for the effectiveness of their work; (ii) workers hold appropriate skills, are knowledgeable and fully committed with companies' methods and goals. This contrasts markedly to normal production control which is essentially focused in keeping production schedules, thus requiring inventory cushions to absorb process breakdowns and unpredictable changes in quantity and product types.

According to TPS, eliminating waste consists in eradicating tasks/elements with no added-value from the client point of view. Seven types of waste are usually identified: overproduction, inventory, transportation (materials), movements (people), over-processing (unnecessary operations), waiting and defects. To eliminate wastes that pertain to such waste types, five principles were established: (i) create value for the customer; (ii) identify the value stream; (iii) create flow; (iv) produce only what is pulled by the customer; and (v) pursue perfection by continuous identification and elimination of waste. These principles are part of the Lean Thinking concept (Womack and Jones, 1996) which is focused on waste, or "muda", elimination.

3. INDUSTRIAL LEAN PROJECTS

This work is mainly based on a number of industrial projects within the area of Lean Management. The projects were developed in companies located in Portugal, by last-year students of the Integrated Master Course on Industrial Management and Engineering (IME) from the Department of Production and Systems (DPS), School of Engineering of University of Minho (UM), Portugal. These individual projects were supervised by the authors of the present study and co-supervised by the host company, and the first occurred in 2001. The projects were mainly conducted according to an action-research methodology in a practical context (Alves et al., 2009).

3.1. Companies characterization

Table 1 provides a characterization of the companies involved in the lean projects, namely in terms of: (i) product type; (ii) national/international (Portuguese companies or international companies located in Portugal); and (iii) number of collaborators.

Table 1.Characterization of the involved companies

Company	Product type	National/ international	Collaborators number
A	Electric wiring systems for automotive industry	International	1916
B	Car radios and heat controllers	International	2000
C	Metallic components for automotive industry	International	340
D	Metal structures for civil construction	National	140
E	Electronic components	International	200
F	Components for automotive industry	International	480
G	Textile components	National	-
H	Metal parts	National	-
I	Flexible tubes for automotive industry	International	110
J	Water heaters and boilers	International	1000

K	Plastic and electronic components for automotive industry	International	-
L	Bus bodies	National	-
M	Illuminated advertising signs	National	9
N	Car radios	International	800
O	Upholstery for automotive industry	National	182
P	Compressors	National	-
Q	Plastic injected parts	National	60
R	Steel processing	National	40

From the eighteen companies involved, half are suppliers to the automotive industry (from these only two are national companies).

3.2. Projects, Lean tools and benefits

A detailed analysis of all industrial Lean projects ranging from 2001 to 2010, which were carry out in partnership with DPS/UM, was conducted. This work intended to reveal the most applied Lean tools, identification of benefits to companies along with the respective quantification. Results were systematized and synthesised in Table 2. The left entry of table 2 includes a company ID which assures companies confidentiality. Each company has conducted one or more Lean projects during the time horizon under analysis.

Table 2. Projects title, Lean tools applied, benefits achieved and project year in the companies studied

Company	Project title	Tools	Benefits	Year
A	Cut sector organization and optimization using JIT tools	JIT	Changeover time reduction (27%) Materials flow simplification FIFO rule implementation Reduction of space needs Elimination of one shift	2001
	Cut sector organization and optimization using SMED and 5S	SMED, 5S	Changeover time reduction (40%) Reduction of waste times Lot size reduction (from 200 to 50 components) Improvement of machines performance	2001
B	Implementation of a Kanban system	Kanban	Process more transparent and easier to control Implementation of a Kanban's Box WIP reduction (from 6 to 2 hours)	2005
	Comparison of the performance between assembly lines and assembly cells	OEE	Implementation of OEE measurement	2005
	Implementation of job rotation	ILOU	Productivity improvement (20%)	2005
	Implementation of Quick Changeover	Quick changeover	Changeover time reduction (about 50% in the main equipements of the assembly lines) WIP reduction (36%) Time reduction from adopting standard work	2006
	Continuous Improvement through Point CIP	Point CIP	General improvements	2006
	Implementation of Standard Work	Standard Work	Productivity improvement (30%)	2007
	Implementation of Point CIP	Point CIP	General improvements	2007
	Improvement of the productivity in the heat control assembly cells	Cells	Reduction of the movements time Improvement of cell organization	2008
	Implementation of production levelling in a pull environment	Production leveling	Reduction in the stock of finished products (20%), saving of capital tied up (around 18000 €) Approach the Every Part, Every Interval (EPEI) to the ideal (EPEI=1) Approach weekly diary levelling fulfilment to a value very close to the ideal value (100%) Accomplishment of the due date negotiate with the clients in 97% of the cases	2008
	Analysis of alternative layouts in an assembly line of car radios	Layout analysis, cont. improvement	WIP reduction (211 to 107 car radios) Workers reduction (27 to 21 workers) Occupied area reduction (358 to 252 m^2)	2008

	Improvement of the performance of teamwork in car radio assembly final cells	Teamwork	Improvement of cell organization changing the operational mode Reduction of the movements time	2009
	Implementation of Ship-To-Line supply	Ship-to-line	Release of warehouse area Reduction of the picking time Reduction of the movements time Reduction of one transport vehicle	2010
	Development of Kanban system in electronic components assembly cell	Pull systems, Kanbans, Cells	Reduction of space (80 to 66 m^2) Change to standard work Reduction of cycle time of one WS (47s to 35s) Reduction of the movements time Improvement of cell organization	2010
	Capacity planning and scheduling of operations in warehouse of materials supply	Capacity planning	Definition of a model to calculate required Human Resources in warehouse of supply materials for assembly lines	2010
C	Application of Lean Manufacturing in Logistics – Raw material supply	Lean logistics, Standard work	Reduction of trucks unloading time Reduction in the identification time of products at the warehouse Reduction of time wasted in movements Reduction of human effort Standard work procedures in warehouse	2009
	Application of Lean Manufacturing in Logistics - Expedition	Lean logistics	Decrease activities with no value, Productivity improvement (26%) Packing standards to reduce the clients complaints Improve warehouse flow of finished goods	2009
	Reduction of Setup Times	SMED	Setup reduction (60%)	2009
D	Application of principles and practices of Lean Manufacturing in metal mechanics company	5S, poka-yoke, pull system, cells, kaizen, VSM	Reduction of distances (25%) through the reconfiguring the layout in cells Lead time reduction (80%) Reduction of the movements time	2010
	Implementation of a production cell	5S, Kanban, TBS, SMED, Cells	General improvements	2008
	Implementation of Pull system in electronic components assembly line	Pull system, VSM	Lead time reduction (31%) WIP reduction (18%, 7600€) Reduction of wait time (82%) Reduced WIP with defects (35%), cost reduction in rework (25915€)	2010
E	Assembly Cells implementation and Lean manufacturing practices in electronic components company	Cells, VSM	Reconfiguration from 5 assembly lines to 2 cells, with reduction of space (50%) and workers (minus 2), improvement of work centres occupation Reduction of WIP (8.2 to 1.3 days) Reduction of lead time	2010
	Application of Lean manufacturing techniques in supply management to production lines and subcontracts	Pull system, Kanbans	Reduction of milk-run distances (20%) Reduction of the number of movements (24%) Reduction of WIP (36%, 8137€) Reduction of waiting time (80%)	2010
	Implementation of SMED in plastic and metallic components production	SMED	Setup time reduction in three workstations (188.15 to 77.8 min, 61.8 to 6.35 min, 58.14 to 9.8 min) WIP reduction (17.05 days to 7.74 days, 318.75€ to 144.38€) Movements reduction (370 to 10 m, 260 to 2 m)	2010
F	Development of a Lean Game to work as a tool to introduce lean attitude on the shop floor	Lean Game	Improvements on training effectiveness	2008
G	Application of Lean manufacturing to improve a laboratory performance	5S, Pull Flow	Performance evaluated, bottleneck identified and reduction of WIP	2008
H	Development and application of a Kanban system in a metallurgy company	Kanbans	Self-regulating material flows Production Levelling Visual management Reduction of temporary stocks	2010
I	Production Cells Supply	Pull systems Kanbans	Process more transparent Easier to control Implementation of a Kanban's system	2006

			Reduction of material stock Reduction of supply failures	
J	Dissemination of BPS (Bosch Production System) and Implementation of Kanbans	Kanbans, visual management	WIP reduction Exemption of the planning task in a production section	2005
	Reconfiguration of Product Oriented Production Systems: an industrial case study	Cells	Process more transparent Flexibility increase Materials flow and supply simplified Easier wastes identification and elimination	2007
	Improvement of performance in a packing section	Point CIP	Cycle Time reduction (6%)	2010
K	Improvement of an assembly line of climate control panels (automotive industry)	Line balancing, visual management	Efficiency improvement (75.13% to 90.87%) Costs reduction (33600€/year)	2004
L	Analysis, simplification and implementation of processes in a bus bodies company	Continuous improvement	Quality improvement (noise level inside the bus) Rework reduction in the paint shop Costs reduction (6156€/bus)	2008
M	Analysis and improvement of a production system of illuminated advertising signs	Standard work, 5S, layout analysis	Implementation of standard work sheets Implementation of a costing system Productivity improvement Quality improvement (less customer complaints)	2005
N	Implementation of production cells	Cells	General improvements	2007
O	Streamline production flow	Visual Manag., Kanban, Levelling	General improvements	2008
	Motivation Improvements through visual management	Visual Management	General improvements	2008
P	Waste Identification and Evaluation	WID	Evaluation of main costs of waste	2010
Q	Impact of Inventories on productivity	VSM	Identification of the main causes of inventory	2010
R	Analysis of Lean Implementation on a Steel Processing industry	VSM	Identification of the main causes of waste	2010

4. ANALYSIS AND DISCUSSION

Forty one industrial projects were developed by IME students, over 2001-2010, under supervision of the authors of the present work. Those projects involved 18 companies, each of which conducting one to 14 projects over the timeframe period. Fig. 1 depicts the number of lean projects that each one of the 18 companies has undertaken over the referred decade.

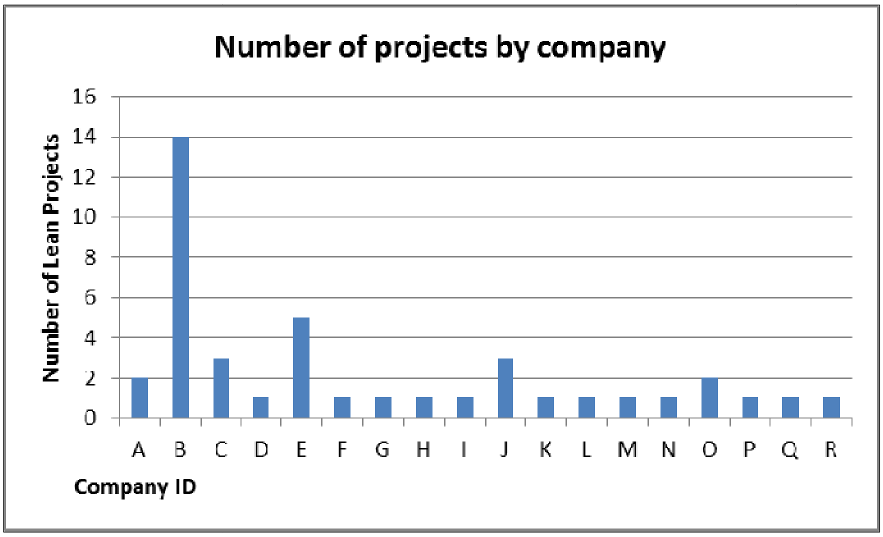

Fig 1. Number of projects developed within the companies

Company B, a large international company and first tier supplier to automotive industry, is by far the company that has implemented more projects. It has conducted lean projects in partnership with DPS/UM year-on-year from 2005 onwards. This company only represents about a third of all projects reported. The company is geographically close to University of Minho and, being immersed on automotive industry sector, is likely to be more aware of Lean Management principles and benefits.

Besides the total number of projects developed within each company (Fig. 1), its distribution over the considered period (2001-2010) provides some relevant information as well (Fig. 2).

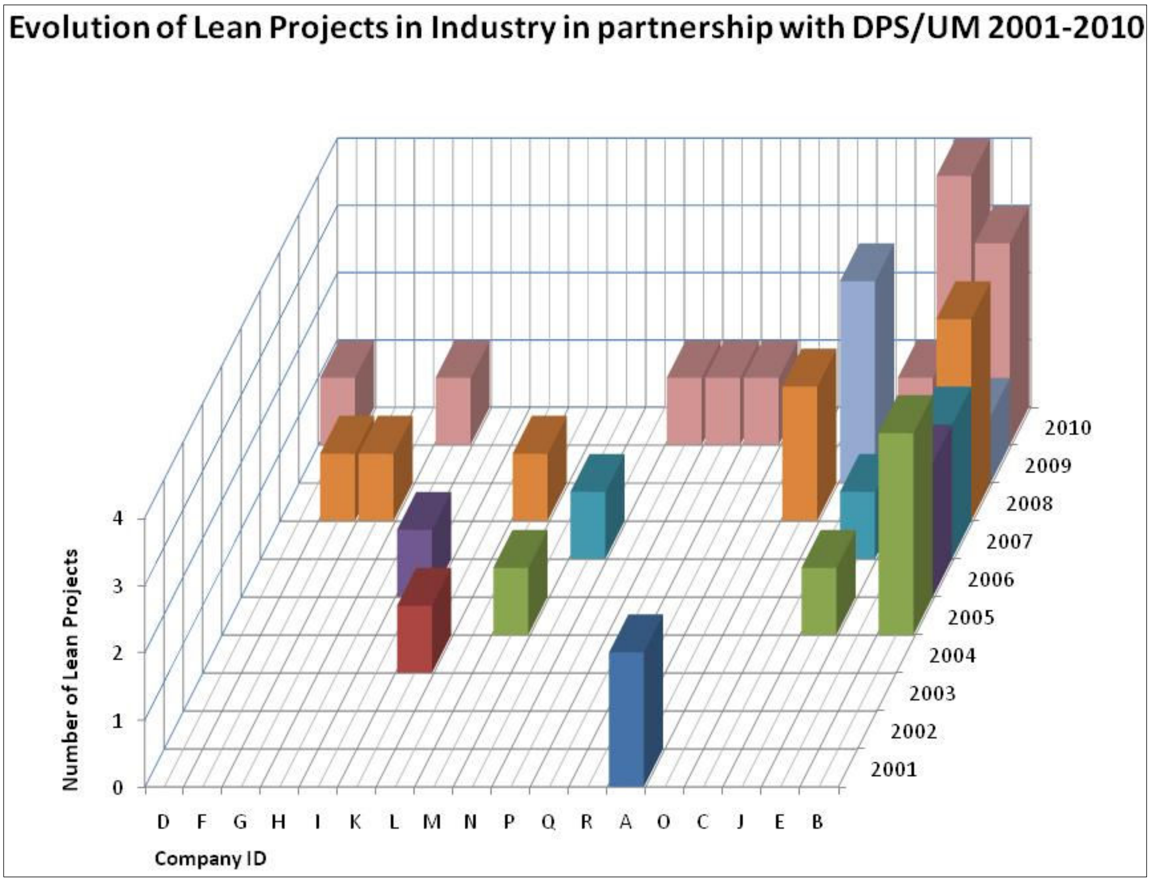

Fig 2. Number of projects developed by year and company

As can be observed (Fig. 2), partnerships with DPS/UM for supervision of Lean projects in industry picked-up momentum about 2005 onwards. The number of companies adhering such projects grown from 3 companies in 2005 to 8 companies in 2010, while simultaneously the number of projects grown from 5 to 14 respectively. While 12 companies have conducted only once a lean project, which seems a rather small number, most of those have done that in the last 3 years which could indicate that new projects could follow in the next years. Some of those companies (D, H, P, Q and R) developed their first project with DPS/UM only in 2010. For some of them that was their first contact with the Lean Management paradigm. Company A, the earlier one holding a Lean project in the time period of the study, has meanwhile moved its operations to another country. By opposite, some other companies successively conduct Lean projects, namely, companies B, E and J. Somehow this may indicate that those companies recognize the importance not only of the Lean Management approach, but also of the interaction with university. Company B, in particular, is regularly involved in Lean projects in interaction with DPS/UM over the last six years. Along with the partnership with DPS/UM, companies E and J are also developing Lean projects with other Portuguese universities.

It is clear from Fig. 2 that the density of projects is higher in the last years. This may reveal an increasing interest of the companies in the Lean Management approach. However, some companies are not familiar with this approach and do not know how to improve their performance. In those cases the student and his supervisor act as disseminators of the Lean culture as this subject has become unavoidable at DPS/UM.

All Lean tools applied in the industrial projects were identified and its use frequency add-up. Results are found in Fig. 3.

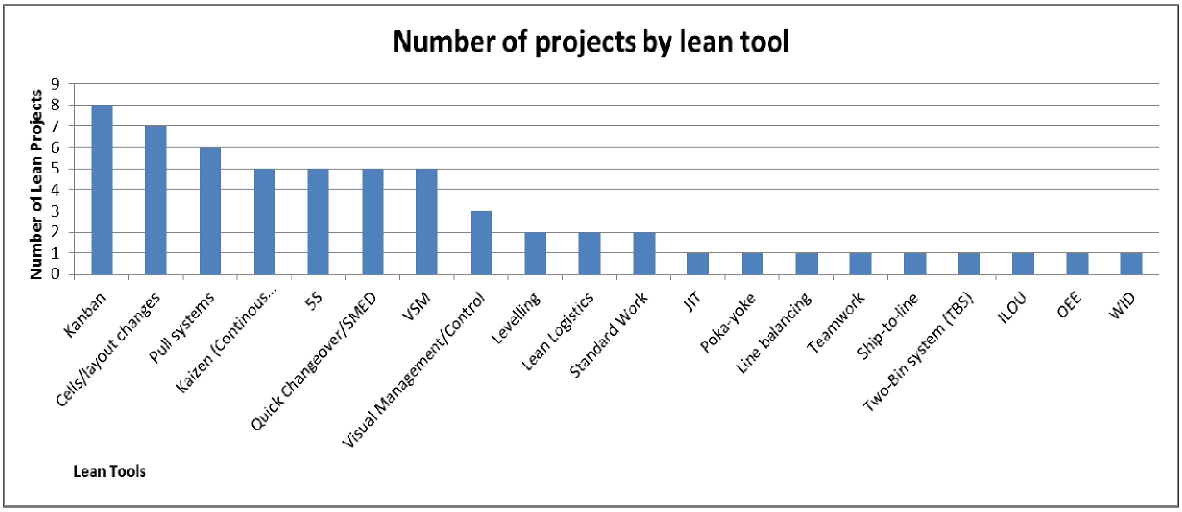

Fig 3. Tools applied in the projects

The implementation of *Kanbans* and *cells/layout changes* constitute the most frequent occurrences. In terms of diagnostic tools, the Value Stream Mapping (VSM) is commonly used. The Waste Identification Diagram (WID) is a new tool under development at DPS/UM and the authors just started its dissemination (Sá et al., 2011).

In terms of improvements achieved by the Lean projects, Table 2 has indicate a considerable number of benefits, some of them more frequent (e.g. WIP reduction, occupied space reduction, materials flow simplification, increase of productivity and reduction of movements) than others. Note that in some cases (Table 2) the benefits were not properly specified (classified as "general improvements"), nor quantified.

Finally, Fig. 4 represents the relation between the identified benefits and the quantified ones.

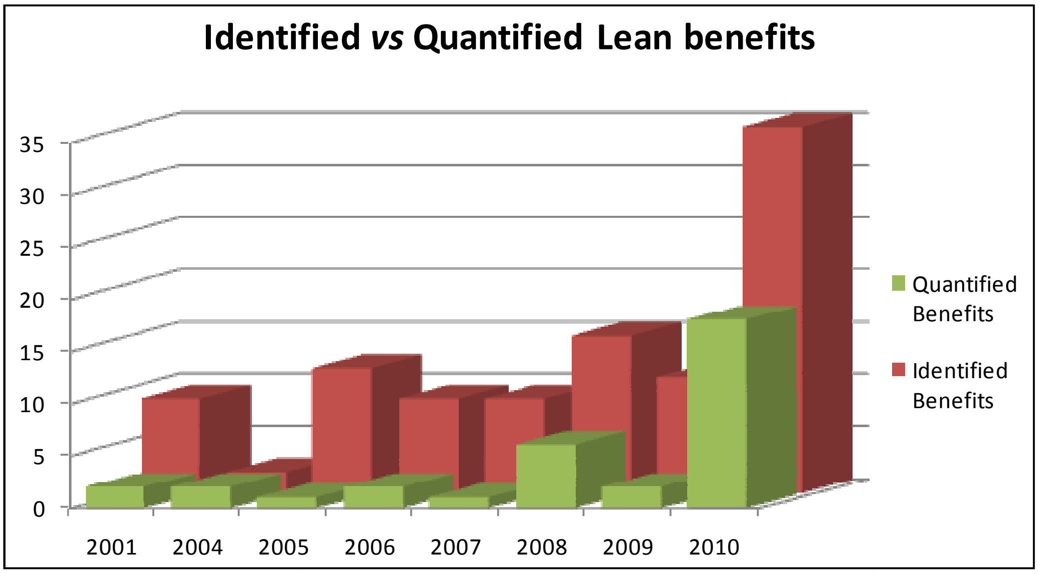

Fig 4. Identified vs. quantified benefits

In 2010 about 50% of the identified benefits were properly quantified, while in the previous years (except 2004) the ratio was clearly inferior. The clear identification and quantification of the benefits is considered an important issue for some of the involved companies. It constitutes evidence of the project success, and reflects the authors' awareness for this matter. The trend for increased quantification of benefits is unobvious in most years of the study period, and although seeming to pick up in 2010, data scarcity does not allow for further extrapolation of such results. The following years should confirm or refute such tendency.

The benefits achieved from some of these projects were published (Cardoso et al., 2008; Costa et al., 2008; Afonso and Alves, 2009; Oliveira and Alves, 2009; Carvalho et al., 2011 and Rocha et al., 2011) contributing thus to the dissemination of the Lean Management approach and concepts, and to speed up Lean awareness.

5. CONCLUDING REMARKS

This paper presented an analysis of industrial Lean projects developed by IME students in companies in Portugal over 2001 to 2010. Although grounded in a small sample, with a total of 41 projects in 18 companies, this work reveals some interesting results. Twenty different lean tools were identified to be used in the industrial projects. The most frequently applied tools were identified. Seven of such tools represent about 70% of the total use of tools in the projects. Improvements achieved by Lean projects were identified to be rather diverse and some, such as WIP reduction or increased productivity, are more frequent than others. Some of such benefits were quantified as well, but the expected trend for increased quantification of benefits is not fully conclusive based on the data collected. The year 2010 gives some evidence for such trend since the share of quantified benefits grown substantially from previous years to about 50%, but the trend could not be confirmed based on a single supporting fact. The next years should clear such reserve on extrapolation of results. The study corroborates the evidence that international companies somehow related to automotive industry are more prompt to partnership Lean Projects with academia. The study also indicates a growth in the number of Lean projects supervised by DPS/UM in the last decade.

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