Final year Lean projects: advantages for companies, students and academia

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Abstract

The Integrated Master Degree on Industrial Engineering and Management, from the Department of Production and Systems of University of Minho – Portugal, requires the development of an individual final project which is almost exclusively developed in an industrial context. The degree is awarded upon the successful development of an individual masters' thesis which directly derives from one such project. The process is triggered by companies which make a general proposal based on specific industrial challenges. The proposal might simply identify the theme and require one or more students to collaborate with them. Many of these projects involve the Lean Production paradigm, which to be successfully implemented, needs a change of culture inside the company that is often promoted by the students themselves. From this partnership there are advantages for both sides: companies, students and academia. Some advantages for students are the opportunity to work in an industrial environment with different professionals, gain some experience, enrich the curriculum, apply and explore the knowledge acquired in the university, transform theories into practice, and develop/apply transversal competences, such as those of teamwork, project management, critical thinking, problem-solving, communication skills, etc. Additionally, students develop awareness for the importance of their professional life, entrepreneurial attitude, and initiative spirit, among others. Beyond the project achievements, such as monetary gains stemmed from shop floor improvements, companies renew their staff, bring new ideas and knowledge, reinforce the links with the university, conduct low cost R&D, uncover new challenges, etc. University and supervisors (academia) gain recognition, practical experience, gain access to case studies and practical examples for classes, and so on. This paper aims to discuss the gains achieved by companies, students and academia, resulting from these industrial projects, and also some drawbacks. These drawbacks are bypassed when healthy partnerships are established, so the paper concludes with some guidelines to achieve this. The methodology applied in this paper uses document analysis for data collection. With respect to data analysis it uses content analysis. The main source of information is a set of master thesis concluded between 2011 and 2013 (inclusive), supervised by some of the authors of this paper.

Keywords: Lean projects, academy-industry partnership, Industrial Engineering and Management Education.

1 Introduction

A recent forum launched by the Portuguese Association of Engineers and the Schools of Engineering (Ordem dos Engenheiros, 2013) intends to promote the debate about engineering teaching and the integration of engineering graduates on the labour market. To achieve a successful integration it is necessary in the first place that the graduates leave the universities well-prepared, otherwise this integration wouldn´t be an easy process for the students that have to face the difficulties of joining the labour market. Therefore, the universities should aim to prepare the students for this big step in their career, by one side providing the right competencies for a smooth entry into the labour market, and by the other, providing inspired engineering professionals that are prepared for the big issues and challenges of the millennium (The Millennium project, 2009; NAE, 2013; UNDP, 2013). This excellence also implies a perfect alignment between Engineering Education (EE) and Engineering Professional Practice (EPP). Unfortunately, it remains the case that such a misalignment has been the source and reason for deep discussion as presented in some reports and papers (Mills & Treagust, 2003; NAE, 2005; OECD, 2006; Duderstadt, 2008; ASCE, 2009; ASME, 2010; UNESCO, 2010; Graham, 2012; King, 2012; Alves et al., 2013). Some of those have designed roadmaps and visions to achieve a better preparation and integration of future engineers. Consensus in all reports is the need to train engineers aligned with present and future company's needs, in order to innovate and provide what society needs without endangering nature and compromising future generations (WCDE, 1987).

This can be achieved with a strong industry-academia relationship grounded on a multitude of partnerships (Project-Based learning, internships, final projects, capstone projects,…) that provide students and faculty with real life projects, following what many authors have been advocating (Mills & Treagust, 2003; Morell, 2008, 2012; Lima et al., 2009; Nair et al., 2009; Aggarwal et al., 2011; Nunes, 2013; Mesquita et al., 2013), and help to create a meaningful work environment. Nowadays, not having this interaction between industry-academia "…is inconceivable…" as stated by Davey et al. (2011) in a final report ordered by European Commission. Even so, these authors identified that the interaction between Higher Education Institutions (HEI) and business is still in the early phases of development. Beyond this, the collaboration with industry will help to define desired profiles for the graduate student by clearly identifying the competencies that a student must possess to be successful on the professional practice (Alves et al., 2013; Cunha et al., 2013; Nunes, 2013). These partnerships must be promoted, not discouraged. The former happened in some engineering schools and programs with the Bologna process (Eurydice, 2010). For example, some engineering schools programs terminated internship period of final year students in industrial context that existed before the Bologna process. In this internship, the student, in a transitional situation, had the opportunity to learn in an industrial environment before performing as a professional. Recognizing the advantages in having this internship, the Integrated Master Degree on Industrial Engineering and Management (IEM) from the Department of Production and Systems (DPS) of University of Minho (UM) kept it, in the format of a master thesis (IEM MSc.) developed in a company.

Some of the authors of this paper have been supervising last year projects of IEM students in an industrial context. These projects focus on designing and improving production systems using the Lean Production methodology (Womack et al., 1990). These are a type of industry-academy partnership with advantages for the students, the industry and academy. This paper intends to discuss the advantages of this partnership and describe the "win-win" relationships that many times have raised sustainable and long-term strategic partnerships. However, this implies an effort, good communication and patience from all stakeholders. With Lean projects, most companies, students and supervisors talk the same language and trust that enables this type of partnership. The needs and potential limitations of this partnership are also discussed in this paper.

2 Lean Production brief literature

Lean Production was disseminated starting in 1990 with the book "The machine that changed the world" from Womack, Jones and Roos (Womack et al., 1990), and can be considered as the western designation of the TPS – Toyota Production System (Ohno, 1988). The main purpose is to "do more with less", i.e. produce exactly what is demanded by customers, using less materials, equipment, energy, effort and capital. The main principles of Lean Thinking are: (i) value definition (from the clients' viewpoint), (ii) value stream identification, (iii) flow creation, (iv) pull production implementation, and (v) perfection pursuit (continuous improvement). By implementing these principles, companies are able to eliminate, or at least reduce, the so-called wastes. Waste is defined as any activity that does not add value to the product, from the customer perspective.

Seven types of wastes were identified by Taiichi Ohno (1988): (i) overproduction, (ii) defects, (iii) inventory, (iv) transports (materials), (v) movements (workers), (vi) waiting and (vii) over-processing. Besides the types of waste, or *muda*, the Toyota Production System also refers the need to eliminate *muri* and *mura* (Emiliani et al., 2007). The Japanese word *muri* means physical strain or overburdening. Any actions such as "bending to work", "pushing hard", "lifting heavy weights", "repeating tiring actions", and "wasteful walk" are considered *muri* and consequently they must be eliminated. On the other hand, the word *mura* can be referred as unevenness or inconsistency. Many forms of *mura* can be found in production, such as operation time or setup time that are not always the same, demand variability, inconsistency in the raw material quality, etc.

To support the implementation of Lean principles and eliminate wastes, companies can use a large set of tools, which includes: value stream mapping (VSM), just-in-time (JIT), standard work, 5S, single minute exchange of die (SMED), poka-yoke mechanisms, among others (Feld, 2000). Many companies are adopting such principles and applying these tools to eliminate wastes in order to reduce cost and improve productivity, as literature has been evidencing (Page, 2007; Taj, 2008; Wong et al., 2009; Silva et al., 2010; Alves et al., 2011; Panizzolo et al., 2012; Mathur et al., 2012).

3 Methodology

This paper intends to discuss the advantages, gains and disadvantages obtained from final year projects of IEM students developed in an industrial environment under an industry-academy partnership. The applied methodology uses document analysis for data collection. With respect to data analysis it uses content analysis. The content analysis performed included the following steps: material organization, data analytical description (codification, classification, and categorization), and interpretation (processing and reflection) (Miles and Huberman, 1994). Processing and reflection are two essential phases since they contribute in discovering and reporting patterns (Richards and Morse, 2013). The main source of information was secondary data: a set of 43 final project M.Sc. theses (IEM MSc.) concluded between 2011 and 2013 (inclusive), supervised by five co-authors of this paper.

During the study period, i.e. 2011 to 2013, a total of 120 IEM theses were concluded, being 74 about Lean or integrating Lean principles, from which 43 were supervised by co-authors of this paper. The Lean projects were developed in companies of goods, such as electronic components, wood furniture, automobile components, and metal structures for civil construction, among others, and services, such as hospitals and others. The theses were collected from the IEM master degree database, available in the RepositoriUM, and from the supervisors.

The 43 MSc. dissertations were analysed with two purposes: 1) identify the benefits achieved by Lean projects developed for the companies involved, and 2) identify the advantages and gains reported by the students, related to the competencies developed within the process, and disadvantages of this process, if any.

The first purpose was researched by looking for benefits reported in the dissertations. These were organized according to the type of waste eliminated/reduced. Additionally, the authors identified the most implemented Lean tools and the ones that being initially considered for application were not implemented. The study also presents the students motives for the latter ones.

Concerning the second purpose, the conclusions of the 43 dissertations were analysed, considering the learning process and the competences developed from the students' viewpoint. From these, 13 students referred some aspects related with this dimension, which were categorized in four groups: 1) challenge in the Lean implementation tools (denotes the resilience of the students); 2) the technical and, mainly, transversal competences; 3) the contact with professional context, and 4) link between theory and practice.

Finally, the supervisors' perceptions, co-authors of this paper, were collected. These are related with the advantages and gains for all (students, companies and faculty), as well as some disadvantages that occasionally either discourage further supervisions by faculty members, or inhibit some companies of promptly accepting future students.

4 Study context

The Industrial Engineering and Management degree of University of Minho is classified as an integrated master degree of 5 years. The students can require a certificate after the third year for employability or mobility reasons. Even though they can carry on to the 4^{th} and 5^{th} year of the IEM to develop a master thesis and conclude the degree. The outline is organized in such a way that the students have project-based learning (PBL) experiences in semesters one, seven and eight.

The IEM PBL methodology implemented in semester 1 provides an integrated approach to multiple contents from within several courses. The main goal consists in designing a product and the respective production system, detailing several key production aspects, and bearing in mind its leanness and eco-effectiveness.

The PBL process of semester 7 is based on the integration of all courses of the semester. In this context, students must develop a project during a semester in order to analyse a production system of a given company and propose improvements. Therefore, students must develop a project in a real industrial context.

Furthermore, this project includes some objectives related to Lean contents, mainly related to one of the courses of the semester.

In the fifth year, students must develop their final year project, i.e. individual thesis, during one and a half semesters. Most of the students develop their project in a company, as an internship, adopting an Action-Research methodology (Alves et al., 2009). They should start the project from mid-November to mid-January and finish it between July and October of the following year. This project was formally designed with 1105 hours of autonomous work and 15 hours of contact with the scientific supervisor. The project, as illustrated in Figure 1, creates the opportunity for the interaction between students, teachers (supervisors) and the industrial companies. In the specific context of the projects analysed in this work, Lean concepts are the main driver for the development of the projects.

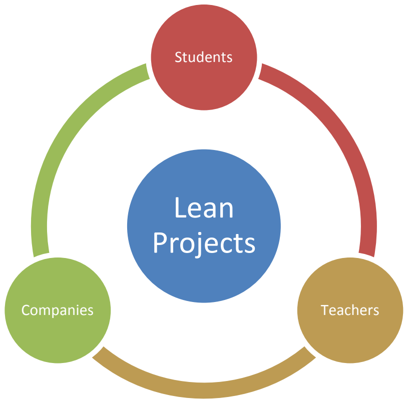

Figure 1: Illustration of the relationship between stakeholders of projects of interaction with companies

5 Lean Projects in industry

The number of Lean projects had a huge increase in the last three years, comparing with the ones conducted in previous years, as published in a paper in 2011 (Alves et al. 2011). This paper presented the number of Lean projects supervised in a decade (2001-2010) by the same supervisors which amounted to 41 projects. From the 120 MSc. concluded in the period 2011-2013, 62% are projects related with Lean Production implementation effort or sustaining this effort (Figure 2).

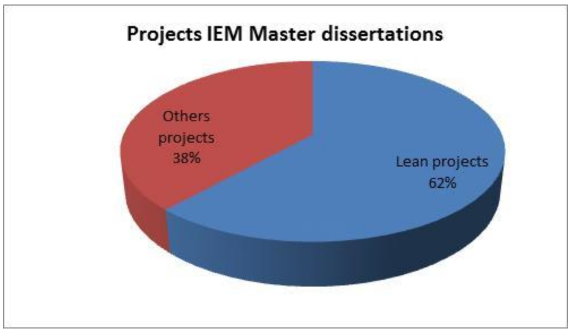

Figure 2: Lean projects developed in IEM M.Sc. dissertations during 2011-2013

The number of Lean projects considered in the current paper amounts to a total of 43 projects in just 3 years (2011-2013), which represents an increase of slightly more than 300%. The 43 projects represent 36% of the total IEM master dissertations, and amounts to about 60% of the Lean-related dissertations over the last 3 years, supervised by 11% of department faculty (5 teachers).

This section presents the results of the analysis conducted, based on the set of 43 dissertations, namely advantages and benefits for companies, students and academia, and the eventual disadvantages.

5.1 Advantages and benefits

The advantages and benefits of the projects are discussed for each stakeholder: companies, students and academy. This discussion is based on the information retrieved from the dissertations and supervisors' perceptions.

5.1.1 For companies

Nearly half the masters' dissertations reported that the initial objectives were fully implemented within the internship period. However, not all the projects were fully implemented during that time, some of the reasons being: the operators change resistance, fear of change, and company mind-set. As one might expect, this behaviour is most frequently referred in the literature (e.g., Ford et al., 2008).

To improve the performance of companies and develop their projects, student's implement some Lean tools. The analysis revealed that visual management, 5S, VSM, *Kaizen*, SMED, *Kanban*, *Jidoka*, *Heijunka* and Overall Equipment Efficiency (OEE) were the most frequently implemented.

For the internships whose proposals were entirely implemented, the benefits for companies were directly linked to the initial objectives. According to Figure 3, the most important benefits after the implementation of the Lean tools were reduced lead-time and reduced setup time, better level of organization, improved productivity and increased production figures. Some benefits were credited from within many waste types reduction, e.g. productivity increase, while other benefits resulted from a single specific waste elimination, such as reduced defects. Moreover, the symptoms of wastes, like *muri* and *mura,* were also reduced, e.g. improved ergonomic conditions.

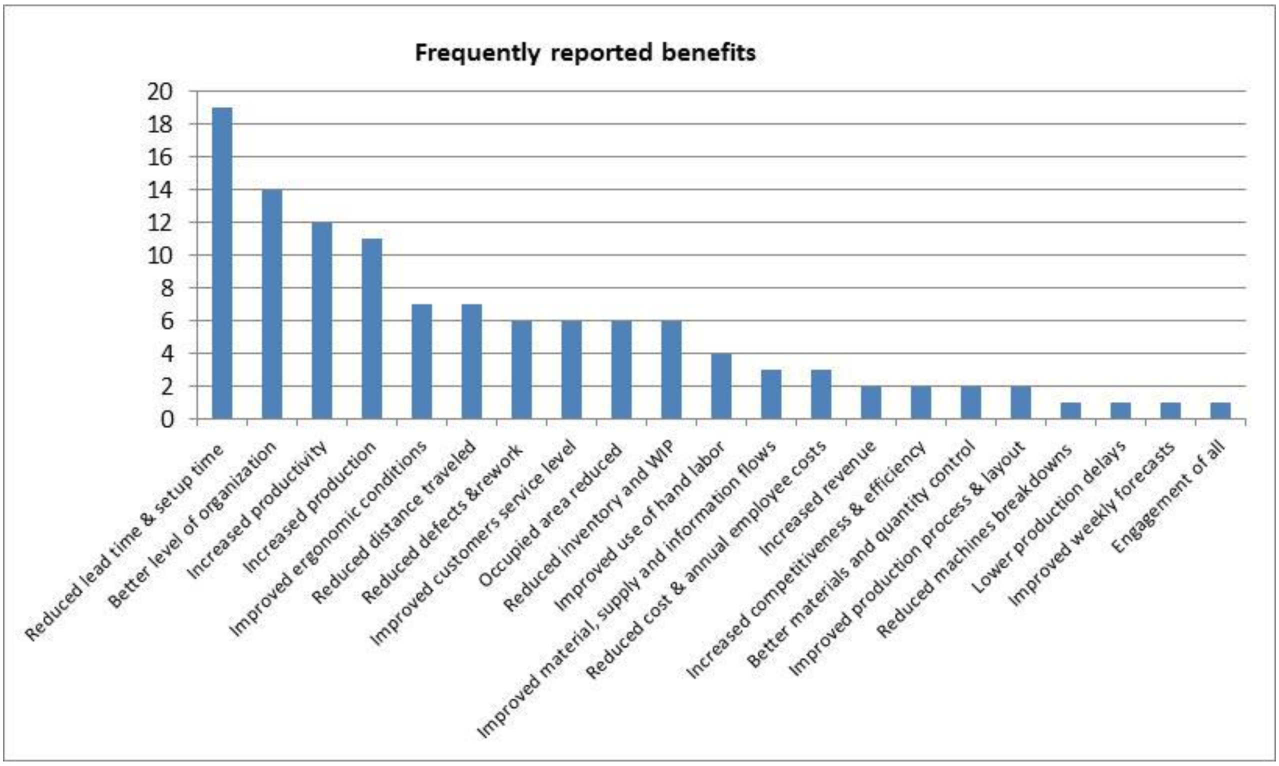

Figure 3: Frequently reported benefits

Beyond these benefits, companies gained a greater awareness for the Lean management methodology, and promoted a culture of wastes reduction, innovation and entrepreneurship, and capacity to accommodate new projects, new perspectives and ideas from someone outside the company.

5.1.2 For students

Doing a dissertation project in an industrial environment puts the students in a real learning context, which requires not only solving engineering problems, by transferring knowledge and skills acquired during the initial training, but also the ability to interact with an organization and its members. The different profiles and backgrounds of organization members may require special communication skills from the trainee. This is, indeed, a very significant learning experience for students who, in many cases, make their first contact with professional reality during this phase.

Findings from the selected master dissertations show evidence of the advantages of Lean tools to help solve most of the problems identified by students in the companies where they developed their dissertation project. In this sense, the dissertation project allowed students to deepen their knowledge in Production Management and Organization, namely, in Lean Production, having the opportunity to link those concepts to practical situations, which are determined by a real life problem from a company.

> "With this project it was possible to acquire greater knowledge in regard to Lean tools, especially concerning production cells. It also allowed to understand the different viewpoints about this theme depending on the different authors and that Lean tools do not necessarily require high costs, but simple and economical solutions, which can result in major improvements. Thus, the first step for the implementation of lean production is to explain to the members involved the main benefits and advantages and that the support of the leaders is crucial for successful implementation of Lean. More difficult than implementing the improvements is to create a culture of maintaining these improvements day after day." (Master Dissertation, Student 10)
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> "It was possible to apply the knowledge acquired during the IEM course. And, in practice, it allowed us to notice that the implementation of Lean is not necessarily expensive and that there are several solutions for a problem." (Master Dissertation, Student 17)
>
> "This project contributed to put in practice what until then was only achieved in theory by the author, supporting in-depth understanding of lean tools and techniques, such as logistics and warehouse organization". (Master Dissertation, Student 18)
>
> "By doing this dissertation based on Lean concepts and calculus of capacity, it was possible to extend our knowledge in regard to these important issues under the Production area." (Master Dissertation, Student 29)

In addition to these aspects, students also referred that transversal skills (e.g. teamwork, communication, resilience, motivation) were key skills to support the implementation of the improvements based on Lean tools. This is because one of the major difficulties identified by students is the resistance to change by the company members, who feel very familiar and comfortable with the existing routines and behaviours.

> "The author concludes this project with greater capacity in leadership and professional relations, management of the needs and personality of the various elements involved in the project, especially the operators. The initial objective proposed - the reconfiguration of the line system with Lean waste reduction - was achieved despite the difficulties inherent to a task of this nature and also the inexperience of the author on projects in a business environment." (Master Dissertation, Student 8)
>
> "The biggest difficulty felt was related to interpersonal relations, due to the existence of a natural resistance to change by some operators, which is a very common factor in business. However, over time and with several explanations of the objectives of the work and the benefits it could bring, this difficulty was overcome. Therefore, it was possible to conclude that for the successful implementation of continuous improvement strategies, there is a need for a receptive attitude and successful integration of all members in the company." (Master Dissertation, Student 9)
>
> "What I learned most from this project was the capacity to communicate and to listen to people. Many times, the operators had interesting ideas, but these were not heard by the company. If this kind of mentality remains in the company, it will be difficult to follow the Lean philosophy, which highlights that we must engage people, always. So, if you can get engineers and managers motivated, surely the results will be even more positive." (Master Dissertation, Student 14)

Thus, it becomes evident that it is not enough to have mastery of Lean tools to implement them, it is also essential to involve people, to create empathy, to be assertive, to learn to argue, to manage and motivate teams, among other aspects that are essential for professional practice as an industrial engineer. Additionally, the project development in an industrial context brings, many times, a job opportunity for the students as they are invited to stay in the company after finishing the MSc.

5.1.3 For academia

The gains for the academia are related with the opportunity to learn with industry. The supervisors, while visiting many companies, have the privileged to really acknowledge the *gemba practices*. Moreover, they enrich their database of problems, and solutions, which can be used to enrich their classes. They can also be motivated to perfect their own Lean journey.

Additionally, the university as a whole might be credited at the long run, for mastering Lean supervisions and attain good industrial outcomes. This is particularly relevant when the students achieve great successes with their projects. Another way of augmenting visibility and global recognizance is achieved through the free access to MSc database (repositoriUM). As an example, the average downloads for each IEM MSc dissertation, during the study period, is nearly 250 downloads and 300 visualizations, in average. Specific thesis might hold much greater figures however, e.g. an MSc thesis developed within the context of Lean applied to an operating room of a hospital had 2086 downloads.

5.2 Disadvantages

Many times, students go to companies that know nothing about Lean, so they have an important role of initiating a complex and difficult journey, since Lean needs a change of paradigm to promote a culture of wastes reduction. When this happen, and the companies accept this change, a transformation begins that brings many benefits. While in other cases, when companies do not accept this change, and do not understand what the students want to promote. Then they feel they have lost time while attempting to do this. For the student, this could be very frustrating. The supervisor can also be somehow involved on this spiral of frustration. The all process can in any case provide a helpful lesson for life.

A disadvantage from academia viewpoint is the reduced number of potential publications out of this type of work. Since academia assessment is mainly based in the number and quality of scientific publications (in accredited journals), this enormously discourage teachers to oversees the students work, and spend a good portion of time on such supervisions.

6 Potential partnership barriers and needs

Final year industrial projects demand a partnership between academy and industry. This partnership works well if all acknowledge their role and a good communication link is established among the interested partners. As referred above, engineering students are better prepared when the learning occurs in an industrial environment, and the companies themselves require good engineers. As such, a "win-win" relationship must be built to achieve such a kind of relationship. This demand, from both sides, trust, engagement and a serious alliance. For example, if a company requires a confidentiality protocol this must be respected by all means, otherwise that could be a barrier for following projects.

In the previous section some disadvantages were reported, which can be regarded as barriers for a healthy partnership. According to Davey et al. (2011) barriers that relate to, or affect, the actual academy-industry relationship or interactions, include:

- Business lack of awareness of HEI research activities/offerings,
- The limited absorption capacity of Small-Medium Enterprises (SME) to take on internships or projects,
- Differing time horizons between HEI and business,
- Differing motivation/values between HEI and business,
- HEIs lack awareness of opportunities arising from university-industry,
- Bureaucracy within or external to the HEI,
- Limited ability of business to absorb research findings,
- Differing mode of communication and language between HEI and business,
- A lack of contact people with scientific knowledge within business,
- Difficulty in finding the appropriate collaboration partner,
- No appropriate initial contact person within either the HEI or business.

When companies are already in a Lean journey some of these barriers are diluted because the student and company are talking the same language. Even in a SME, a Lean project has space because wastes can be found in any type of company, for example in Carvalho et al. (2011), a medium metal structures company, achieved many benefits with a Lean project. But, sometimes, this is not enough or the company is not accustomed working with HEI and the partnership has specific needs to be healthy. So, as a final conclusion, taken from Nunes (2013), some practice guidelines of partnerships academy-industry are presented:

1) Start with a shared vision and develop a strategy
   - Build partnerships on a set of principles. Spend time on the agenda of each party.
   - Industry-university collaboration works best with big framework agreements based on broad principles.
   - Partnerships need to be flexible.
   - Develop win-win partnerships.
   - Non-strategic partnerships could be able to give promising results – they can grow and develop into strategic partnerships over time
2) Long-term partnerships generate the largest benefit:
   - Companies are often averse to invest over the very long term.
   - Universities usually are not well-suited for doing research that business immediately needs.
   - Strategic partnerships should be based on a kind of complementary relationship where companies go to university to do something with the ability that they don't possess, rather than for using a cheap source of research.
3) Put the right people in charge. Academics with understanding of industry researchers and company researchers opened to engage with the Institute on a regular basis.
4) Intellectual property could not become a problem for partnership.
5) Results of a strategic alliance cannot be measure by using metrics such as papers published or patent applications filed.
6) Knowledge of partner's needs. Companies don't like projects that do not generate internal support in their organizations.
7) Time and leadership is necessary to develop partnerships. It takes work and leadership from the top to create and maintain good relationships between companies and academia.

7 Final remarks

This paper presented an analysis of 43 MSc dissertations developed in an industrial context over a three-year period, which focused on the application of Lean Production and on the identification of the main Lean Tools used to reduce shop-floor waste, and thereby improve productivity and reduce cost. The chosen dissertations are all linked with the IEM degree from University of Minho, and were all supervised by some of the co-authors of the study.

The study focused on identifying the major benefits for companies, for the students themselves and for supervisors. The companies generally improved their shop-floor efficiency, which normally translates into economic gains, lead R&D a fraction of the cost only, and uncover new challenges and new ideas. A number of advantages for students were identified, namely the opportunity to work in an industrial environment, gain experience, apply technical competences, develop teamwork capabilities, project management, critical thinking, problem-solving and communication skills. The University might gain industrial recognition while supervisors gain more practical experience, and access to case studies to show in classes.

Some drawbacks were also identified, which mainly related to frustration among the main project stakeholders, when the project failed to fully accomplished its goals, or failed to sustain its compliance to Lean methodology. Another source of entropy is that the academia assessment instrument, applied to the supervisors, being essentially made through quality scientific publications, which does not directly derive from the supervision activities.

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