

Lean, Six Sigma and Lean Six Sigma in Higher Education: A Review of Experiences around the World

Sylvie Nadeau

Department of Mechanical Engineering, École de technologie supérieure, Montréal, Canada
Email: sylvie.nadeau@etsmtl.ca

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Abstract

Economic, demographic, social, technological and political changes worldwide are putting academic institutions under intense pressures. In response, universities are adopting new managerial approaches to their activities: lean, six sigma and lean six sigma. A portrait of this experience emerges from reviewing the literature published over the past decade using the databases Compendex & INSPEC/Engineering Village and Scopus. These approaches have been applied primarily on a highly localized basis to teaching-related processes or to services such as financing, data processing and building maintenance. Some of the challenges raised are not unknown outside of the university setting. The complexity of universities, the difficulties of interpreting notions such as the client, added value, and the connexions between teaching and research, make the implementation of these approaches difficult. While the few measured results available suggest that they do hold promise, their impact remains to be determined.

Keywords

Lean, Six Sigma, Higher Education, University

1. Introduction

The shifting dynamics of the world economy are forcing governments to re-examine the models applied in public administration. Changing demographics are shaking up conventional financing structures in developed nation states. As societies become more knowledge-based, they feel an increasing need to improve access to higher education [1]. Among the consequences of these changes are increased competition among universities [1] for continued funding of operating budgets [2], demands to improve accountability [1] [3] [4] [5] and major (often

draconian) budget cutbacks [1], often leading to erosion of student-professor interactions and increased sizes of groups filling lecture halls [6] [7], increased workloads for professors and much attrition following retirement of faculty members [6]. Financing of research becomes anaemic, further exacerbating already intense competition between universities [2]. Universities are all soliciting more and more the support of philanthropists (who are also more demanding) to maintain operations, and are increasing or planning to increase tuition fees [6].

Student recruitment is reaching beyond national borders [8] and training is becoming personalized [9]. Universities are perceived as playing a frontline role in the dash towards worldwide mobility of populations: international students often stay in their host countries after graduating, thus contributing to labour force meshing with the alma mater and to the economic growth of their adopted country [1] [10]. Universities are scrambling to diversify their clientele in terms of age, cultural background and prior training [1] and to recruit better students [2] and more qualified professors [8] both locally and internationally, in some cases even encouraging the importation of foreign university programs to national soil [1]. Such internationalization initiatives often heap excessive workloads on faculty members [11].

Technological change and communications occur at such speed that a university education can become quickly obsolete without continued training “delivered on a just-in-time” basis [12]. Meanwhile, students have become better informed and more selective [1] [2]. Virtual or digital university [7] is now a reality, accelerating in its wake a race towards the development of innovative pedagogical methods and materials [7].

The role and responsibilities of a university in a society more and more preoccupied with sustainability are changing [13]. It remains necessary to strive for academic excellence, while “promoting and implementing sustainability practices in teaching, research, community outreach, waste & energy management and land use” [13]. It goes without saying that universities, be they private or public, have come under tremendous pressure [14].

Literature published in the 1990s shows that total quality management (TQM) was the most popular technique in the university community for meeting the challenge of what were then incipient realities, the United States of America being the leader in this type of approach, with faculties of administration and engineering behind most of the initiatives [2] [15] [16]. The popularity of TQM then faded in this community as the lack of clear connexions to the strategic aims of the institutions became apparent [15]. The literature published since the year 2000 reveals a greater interest in contextualisation of lean manufacturing [17] [18] [19].

The aim of this review of the literature is to provide a worldwide portrait of documented experience with the introduction of the lean (waste management focused application of the just-in-time production philosophy), six-sigma (structured improvement management approach focused on an organization’s strate-

gical clients and projects) and lean six sigma (process management and improvement approach based on lean and six sigma) approaches into university communities: the processes and outcomes targeted, the preferred tools, the results obtained, and the challenges and opportunities identified.

The results of our search suggest that there has not been to date (to the best of our knowledge) any conclusive and compelling finding with regard to the use of these new managerial approaches in the university environment in general. Many universities are still on their first experiences with the use of these methods. Although they hold promise, their impact should be interpreted with caution. Immense challenges continue to hinder their successful development.

2. Methodology

The literature examined includes peer-reviewed articles (reviews and conference proceedings), monographs and reports published during the years 2000-2016, retrieved using the Compendex & INSPEC/Engineering Village and Scopus databases. The keywords used (English with French equivalent) were: lean, just in time, agile, university, educational institution, academic, education and higher education. The snowball effect was used to saturate the procedure. The search was focused on titles and abstracts. The articles thus retrieved were read and sorted on the basis of their relevance to the subject under study, their methodological quality and their clarity. More than 110 documents were thus analyzed over a period of about four months.

As proposed previously [1], the results were sorted also into four geographic regions: the Americas (USA, Canada, Mexico), Europe (United Kingdom, Finland), Middle East and Africa (Saudi Arabia, Southern Africa) and Asia Pacific (China, India). These groupings reflect similarities in terms of the drivers of change, be these political, economic or sociocultural as proposed by Brookes and Becket (2007) [1]. The goals of the intervention, and the processes in particular, were divided into two types, namely primary and assistance. Primary processes were separated into operations and tactics. The preferred tools were ranked according to a structure proposed previously [20] for lean six sigma intervention programs in the university environment.

The challenges of introducing and implementing lean, six sigma and lean six sigma were enumerated then divided into two categories, namely characterizing manufacturing settings versus encountered only in academia.

3. Results

The lean, six sigma and lean six sigma approaches to management are still emerging in the university setting [21] [22]. **Tables 1-3** suggest that American and British universities are the most committed to their implementation. Mexico, Finland, South Africa, India, China and Saudi Arabia universities are involved. The targets of the interventions (**Tables 1-3**) are mostly primary processes (operational and tactical) associated with the university in its teaching capacity, and supporting processes associated with financial and data processing

Table 1. Uses of the lean approach in universities.

Geographical region	References	Target of the intervention (processes, outcomes)	Universities/countries involved	Preferred tools	Results documented
Americas	[19] [23] [24] [25]-[31]	<p>Primary processes (operational)</p> <ul style="list-style-type: none"> • Student admissions • Improving course content • Review of marks • Service requests by students at guidance/health centres • Distribution of bursaries and financial support <p>Tactic decisions</p> <ul style="list-style-type: none"> • Program improvement • Hiring of professors <p>Processes of assistance</p> <ul style="list-style-type: none"> • Moving students into residences • Purchasing, payroll, payment, contractual agreements for architecture and engineering services • Distribution of keys • Budgetary exercises <p>Retention of students</p> <p>Improving information flow within project courses</p>	<p><u>Mexico</u> UPAEP U.</p> <p><u>USA</u> Oakland U., South Dakota State U., U. of Central Oklahoma, U. of Iowa, U. of New Orleans, Bowling Green State U., U. of Scranton, Rensselaer Polytechnic Institute, Old Dominion U., California Polytechnic State U.</p>	<p>Value stream mapping, Five why's, Kaizen, Four waste categories, Poka-yoke, Jidoka</p>	<p>Before intervention, 72% of the undergraduate mark review process and 90% at the graduate level was non-value-adding. The process of student moves into residences used to take 4 hours and now takes 1.5 hours. 96% of the new process now includes value-added activities.</p> <p>The employee payroll process has been reduced from 20 days to 45 minutes from request to the actual pay process.</p> <p>Review of the faculty member hiring process led to reducing the number of steps from 30 to 25 and the file processing time by 54%. Waiting time for a first appointment at a student service was 16 days.</p> <p>Requests are now processed and students get an appointment the same day.</p> <p>For health services the waiting time was reduced from 20 min to 2 min.</p> <p>The response times at admissions passed from 2 - 3 weeks to 1 day.</p> <p>Before the intervention, 35% of project course management activity was non-value-adding. After an electronic platform of information and document exchange between students and professors was set up, these activities were decreased to 6%</p>
Europe	[9] [21] [22] [32] [33] [34]	<p>Primary processes (operational)</p> <ul style="list-style-type: none"> • Student admissions • Delivery of feedback on student assignments • Exam rewrites • Administration of research financing • Evaluation of sabbatical leaves <p>Tactic decisions</p> <ul style="list-style-type: none"> • Program improvement • Hiring of personnel • Decision-making by various committees <p>Assistance process</p> <ul style="list-style-type: none"> • Financial data reports • Planning of building maintenance work • Offering extension programs • Payroll and employee payment 	<p><u>United Kingdom</u> Royal Institute of Technology, Cardiff U., Nottingham Business School, Portsmouth Business School, U. of St Andrews, Warwick Business School</p> <p><u>Finland</u> Turku U. of Applied Sciences</p>	<p>Rapid improvement workshops/events, Process mapping, Value stream mapping, Flow charts, Written process cards, Five why's, Fishbone diagram, Nominal grouping techniques, Six thinking hats, Competency framework, Log frame matrix, Visual management, Team information boards, Root cause analysis</p>	

Continued

Middle East and Africa	[35] [36]		South Africa	Value stream mapping, Root cause analysis, Ishikawa diagramming, Five why's, Visual management, Standard operating procedure	Management of a financial aid service waiting line reduced from 50 students before to 10 after the intervention.
Asia Pacific	[37]	Primary process (operational) of course content improvement	India		

Table 2. Uses of six sigma in universities.

Geographical region	References	Target of the intervention (processes, outcomes)	Universities/countries involved	Preferred tools
Americas	[38] [39] [40] [41]	Primary process (operational) of student admissions; Retention of students; Graduation	USA Rose-Hulman Institute of Technology	Process map, Statistical analysis, Ishikawa
Asia Pacific	[42] [43] [44] [45]	Ratio admission/level of placement; Training quality; Retention of students; Graduation	China India GITAM U. Visakhapatnam Shri Krishan Institute of Engineering and Technology	

Table 3. Uses of lean six sigma in universities.

Geographical region	References	Target of the intervention (processes, outcomes)	Universities/countries involved	Preferred tools	Results documented
Americas	[46] [47]	Primary process (operational) of student admissions	USA U. of Central Florida	Value stream mapping, Process map, SIPOC (suppliers, inputs, process, outputs, customers), Surveys, Critical to quality tree diagram, Balanced scorecard, House of quality, Benchmarking, Statistical data analysis, Fishbone diagram, Failure mode and effect analysis, Cost of quality	Cycle time of application for admission was improved, the target being 10 working days.
Middle East and Africa	[5] [48]	Primary processes (operational) <ul style="list-style-type: none"> • Improvement of course content • Distribution of bursaries and financial aid • Student graduation logistics • Welcoming new students Tactic decisions <ul style="list-style-type: none"> • Program improvement • Welcoming new staff Process of assistance <ul style="list-style-type: none"> • Purchasing payroll/payment • Management of profiles, data processing services • Catering services • Management of controlled materials • Identification of sources of revenue Throughput rate	South Africa Tshwane U. of Technology Saudi Arabia King Abdullah U. of Science and Technology	Organizational diagram, Project charter, Voice of the customer, SIPOC, Process modeling, Critical to Quality Output Measures, Statistical data analysis, Ishikawa, Pareto, Scoping frame, Improvement priority matrix, 5 why's, Boxplot, Scatterplot, Risk assessment, Elevator speech	

services and building maintenance activities. Processes associated with universities in their research capacity were not examined in detail for the moment. The basic tools (Tables 1-3) are preferred. Very few quantitative measurements of results (Tables 1-3) are documented (e.g. cost/benefit analyses), leading some authors to conclude that much more work is needed before making any claims about what can or cannot be achieved using these approaches [22]. The interventions counted are focused on eliminating wasteful expenditures. As far as we have been able to determine, no study of the impact on occupational health and safety (OHS) following introduction has been documented. The challenges (opportunities) encountered in the university setting and also in the manufacturing sector (in which *lean* and its derivatives developed) can be summarized as follows:

- Misunderstanding concepts, tools and vocabulary [19] [22] [35];
- Lack of commitment and leadership from upper management [19] [22] [24] [35] [49];
- Deficient commitment and training of staff [17] [19] [22] [46] [49] and students [24];
- Lack of clarity and openness in communications [19] [22] [35] [49];
- Little resources allotted to the interventions [19] [22] [23] [35] [49];
- Poor alignment and matching of interventions with the strategic plan of the organization [19] [22] [35];
- Deficient definition of the problem to be solved [23];
- Insufficient planning, coordination and coherence of the actions and the changes brought to processes [22] [32];
- Resistance to change, inadequate justification, culture of blame, poor management of conflicts within the organization [22] [23] [32];
- Rapidly changing external environment [23].

Challenges that are specific to the university community arise primarily from:

- The complexity of the community and its processes [4] [5] [22];
- Dearth of documented experience in this sector [21] [33];
- Difficulties of contextualizing certain tools in the sector [21];
- Difficulties of defining who the client is and what added value is for the client [22] [25];
- At times deficient links between research and teaching activities [5];
- A negative perception among faculty [26], who feel that its academic freedom is being compromised [32].

4. Discussion

Based on the documented experiences of universities attempting to improve the efficiency of their administrative procedures or the overall quality of student education by applying lean, six sigma [50] and lean six sigma [51] methods, it appears safe to say that such an approach is still quite novel in academia. It has yet to be introduced into the university system as a whole, and measured results are limited to a small number of cases. Universities are complex socio-technical

systems [5] [52], in which multiple processes, goals and priorities are in dynamic, non-linear and often synergic relationships, expectations of several parties must be taken into consideration, and uncertainty affects outcome. The documented experiences concern primarily processes in which such interdependencies are less significant [1], which facilitates appropriation but yields findings that are much more localised [1]. “The primary mission of universities is the production, creation, preservation, transfer and dissemination of knowledge. Their dedication to teaching and research and their service to the surrounding community constitute the common foundation on which they have built the specificity of their sector” (translation of [4]). The processes that have been improved so far are teaching-related; however, there is certainly interdependence between teaching and research, knowledge being the focus of both roles [53]. The literature also reveals that broadening of the applicability of lean manufacturing ideas to other business sectors has advanced [54], that this is a very delicate operation [32] and that the experience of universities is not exceptional in this sense [9] [21]. Some observers nevertheless view the lean method and its derivatives as being suitable for academic institutions and holding much promise for increasing the competitiveness of universities that make a serious commitment to applying them [23]. Like any organisation, a university must deal with uncertainty and with continued change at an ever-increasing pace. It must provide itself with robust tools to perform in an environment fraught with risk and to remain agile in the face of uncertainty. In this age of increasing competition and resource scarcity [55], only those universities that have the wherewithal to distinguish themselves [56] [57] are likely to note a gain in competitive advantage. Will lean, six-sigma and lean six sigma practices be enough to sustain such advantages over the long term? The few conclusive results available do not provide a definite answer to this question for the moment.

The principal obstacle to broader use of these new managerial approaches to improving efficiency is encountered at the step of defining the client and added value [2]. Who is the client of a university? The correct answer to this hard question [7] is crucial for the successful implementation of a lean solution [9] [22]. This has been researched extensively since the first attempts to introduce total quality management in the 1990s [58] and remains the subject of debate [9] [52] [59] [60]. While some researchers state unequivocally that the client is clearly the student (e.g. [14]), others involved in the same intervention within the same institution (private or public) consider the student, parents, industry, donors to the foundation, university, alumni, and society at large to have an equal stake (e.g. [30]), not to mention the granting organisations and institutions that invest directly in research and development in collaboration with the university [2], accreditation organisations, junior colleges or other universities, and professional organisations [23]. It is noted in the published literature that several social partners with differing agendas are involved in shaping university education [2] [9] [52] and that a given social partner (e.g. the student) may play more than one role within various university activities [2]. An interesting model of this phe-

nomenon and the associated interactions between social partners and the university has been proposed [53]. The definition of the client must be consistent with the role of the university, for example, preservation of the culture, scientific research and service to society in a communist country [45], creator and guardian of knowledge in British society [61].

The client has been defined as “an individual or group who has the power to specify and pay for services or products they want and value” [9]. Several models have been proposed to resolve the difficulty of defining such persons in the university setting: based on consideration of all stakeholders and their relative importance, using the quality triad concept to clarify the roles of stakeholder groups, considering future employers as clients and graduates as products, considering education as a service to students, based on three categories of classification (input clients, processed clients, output clients) or on two categories: primary and secondary clients depending on their position within or outside of the institution or on the frequency of their interactions with the institution [2] [60].

Many universities prefer to simplify the process of introducing the lean approach by focusing solely on the students [62]. This has had numerous documented consequences [59]. Among others, the student-client approach exposes faculty members and their support staff to increased OHS risks, especially psychosocial [63]. Others propose considering the students as collaborative partners on the same level as the other stakeholders, and reminding them of their responsibilities towards others as well as themselves [59] [64].

The notion of client thus seems to be a sensitive issue in the university setting, albeit one that has to be resolved adequately if efforts to improve processes are to be successful. One promising avenue appears to be identifying the key players in and end-users of each process under examination [28]. Defining quality in the university setting can become a difficult and perilous exercise [2] due to the complexities [65]. Several definitions have been proposed depending on the perspective [60] [65] [66]. Once the client is identified clearly, quality and added value are defined accordingly. While it is always necessary to remain aware of non-quality, over-quality is an equally problematic issue, one that was not broached in the literature examined.

5. Conclusions

This review summarizes the documented experiences (2000 to 2016) of universities with use of lean, six sigma and lean six sigma approaches to improve administrative efficiency and the overall quality of the education received by the students. We identified the goals of the interventions, universities particularly committed to applying this type of approach, the preferred tools, the findings (when presented), and the challenges encountered.

We have thus demonstrated the emergent character of the introduction of lean, six sigma and lean six-sigma philosophies into the university setting, as well as their rather localized deployment within the complex systems under ex-

amination. Several challenges stand in the way of their successful application, including proper definition of the client, of added value and of the associations between teaching and research. Various avenues for resolving these difficulties have been proposed. The impact of such efforts, particularly with regard to OHS, is much less documented, which we regard as noteworthy, given that the impact of lean manufacturing on OHS, as described in the literature, may be positive or negative, due often to factors that remain to be identified. While approaches of this sort appear to hold promise, it is still too early to conclude that they will allow universities to gain a competitive advantage.

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