Lessons from higher education: adapting Lean Six Sigma to account for structural differences in application domains

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Abstract: Lean Six Sigma is applied in a wide range of economic domains ranging from industry to services to healthcare. These are all domains that have markedly different structures. Recently a set of papers has appeared indicating that the successes in applying Lean Six Sigma to new domains such as government, healthcare and education are falling short of expectations. We discovered by exploring the case for Lean Six Sigma in higher education a set of structural variables that explain differences in application domains. These differences are relevant to the application of Lean Six Sigma in general. These differences and the extent in which Lean Six Sigma can cater for them explain some part of the successes and failures in the application of Lean Six Sigma outside its domain of origin: high volume, repetitive production.

Keywords: Lean; Lean Six Sigma; Six Sigma; higher education; analysis framework; application domain of Lean Six Sigma; services; government; success and failure of Lean Six Sigma applications.

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1 Lean Six Sigma falling short?

Educational institutes in many countries are faced with the challenge to educate more students at a higher level at less cost. Education is an important factor in worldwide competitiveness of countries and companies. At the same time governments are facing serious budgetary constraints forcing cuts in budgets for education. Students facing higher tuition fees demand better quality. In this context it is understandable that institutes in higher education (HE) turn to Lean Six Sigma to improve quality and drive costs down. Lean Six Sigma has proven successful in other domains in improving performance. There is thus a clear prima facie case to be made for Lean Six Sigma in HE. This case is further strengthened by some initial experiences with the application of Lean Six Sigma to HE (Emiliani, 2004; Balzer, 2010).

Various authors have evaluated Lean Six Sigma practices in relatively new application domains such as healthcare and education. The general tenor seems to be that the Lean Six Sigma projects and their impact fall short of expectation and performance compared to other domains. The reasons for this failure can be grouped in two groups: one, general (change) management related issues; two, structural, domain-specific issues. Antony et al. (2012) conclude that Lean Six Sigma is fit for higher education but that application is lagging far behind compared to other application domains. They note that Lean Six Sigma for HE faces various challenges. They name lack of visionary leadership and process ownership as examples. This lack might be more prevalent in higher education than in other application domains but does not relate to the structure of the HE domain. The redress would be, for example, in change management practices. In the case of Lean Six Sigma healthcare, Mazzocato et al. (2010) conclude after an extensive review that Lean Six Sigma application is successful but it falls short of its potential. The applications are mainly local, at the operational level and of an instrumental nature. They attribute this to, amongst other things, a lack of senior management involvement. Radnor et al. (2013), Radnor and Osborne (2013) conclude in a similar vein that Lean Six Sigma practices in (public) services have fallen short of their potential. They seem somewhat less positive about the actual and potential benefits. More importantly, however, they attribute the lack of progress to “a lack of consideration of the underlying logic and theories of service management”.

In this paper we do not want to argue with Antony et al. (2012) that general and change management practices are not important and need no improving. General and change management capabilities in HE might indeed be poorly developed. Though there is no indication that these are actually less well developed in HE than, for example, in industry. Nor is there any indication that differences in general and change management practices explain the differences in success. The case we want to make is that education and other domains such as government might be structurally different in that it involves, for example, strong customer participation in the production of the service. Overlooking structural differences would have as consequence that even if general and change management issues are addressed, the Lean Six Sigma application would still fall short.

It would do so because Lean Six Sigma as it currently stands is not fully fit to take into account the structural differences in the domain of higher education. What are these structural differences? And ultimately, what is Lean Six Sigma HE about? These are not so obvious questions. In trying to answer them we first consider our basic premises.

We investigate in Section 2 some basic premises of Lean. One of these is that Lean Six Sigma is a general operations management strategy. As an operations management strategy it should account for differences in structures in the application domains related to customers, suppliers, technology, etc. Section 3 provides an overview of six variables describing structural differences in domains. These variables might explain some causes of the shortfall in Lean Six Sigma success in some domains. The initial differences in success can be understood when considering the specific setting in which Lean Six Sigma and Six Sigma have been developed. Section 4 provides a description of the domain of higher education in terms of our six variables and the potential impact they have for the Lean Six Sigma practice. We claim, in Section 5, that these variables require possibly adaptations in the Lean Six Sigma approach if not its practices. The exact impact of the six variables and how to measure these in terms of uncertainty are open questions. As is the exact nature of the relationship between these variables, how they influence, strengthen or weaken each other. These are two issues that require further research as we describe in Section 6.

2 Lean Six Sigma as an operations management strategy

This paper begins when we revisited our own efforts in applying Lean Six Sigma in the field of higher education. Exercising some Hansei the key questions were why is or ought there to be anything such as Lean Six Sigma HE? And, if affirmative, what is it about? Can we apply Lean Six Sigma just as-is to the domain of HE? It might be that Lean Six Sigma theory[1] is an universal theory that needs no adjustments. Any general theory must have principles and concepts that are valid across domains. Otherwise it is not a general theory. But when it is too general it becomes void of explanatory power and practical relevance. Several publications seem to indicate that the Lean Six Sigma theory as-is falls short when applied in new domains and seems to be in need of some adjustments. We are investigating a way to describe structural difference in domains. To do so we introduce an analysis framework with variables that denote the structural differences.

To identify the variables of an analysis framework we turn to our basic premises. The first premise we would like to address is that Lean Six Sigma is an operations management strategy. As such it stands in a long and broad tradition in which various concepts and techniques have been developed. Some examples are Little's law, visual management systems and statistical process control. Operations management is based on the idea that all organisations are processes (Slack et al., 2010). Specifically the transformation of input into products and services.

> "Operations Management deals with the design and management of products, processes, services and supply chains. It considers the acquisition, development, and utilization of resources that firms need to deliver the goods and services their clients want." MIT Sloan

As operations management strategy, it needs to deal with four aspects of bringing about/producing services and products (Slack et al., 2010):

- Volume – how many products or services are made by the operation?
- Variety – how many different types of products or services are made by the operation?
- Variation – how much does the level of demand change over time?
- Visibility – how much of the operation's internal working is 'exposed' to its customers?

Items one through three together represent output and demand variability (variable A). They all are concerned with various aspects of demand. Visibility refers to the extent in which the consumer is involved in production of the good or service. The greater the involvement the more visible the internal operations are. This aspect is covered by the more general notion of co-production (variable B). Co-production refers to the fact that in many services the customer is exposed to the internal workings of operations and also actively involved in the creation/production of the products and services. Co-production loosely defined includes active participation of professionals and clients in the process of delivering products and services on an equal and reciprocal basis.[2] E.g. a patient is not a passive subject undergoing treatment but often actively involved through exercising, therapy, dieting, etc. and involved in the decision-making regarding the methods and technologies used.

In organisation theory of Thompson we find another basic premise for Lean Six Sigma as an operations management strategy. Organisational forms adapt based on the constraints and contingencies posed the environment and technology used by the organisation. Constraints in this context are conditions that are fixed for a meaningful period of time to which the organisation must adapt. Some conditions might become contingencies that might or might not vary and are beyond the direct control of the organisation. The environment refers to the whole of four elements: customers and distributors; suppliers of materials, labour and capital; competitors in markets and for materials; and regulatory bodies/settings. Thompson refers to technology and dependency as two important aspects that are sources of contingency and constraints. Technology and dependency are thus focus points for operations management strategies. By technology (variable C) Thompson refers to the techniques used to produce the good or service. E.g. in the context of a school the technology is the pedagogical methods used, in mental healthcare technology refers to the therapeutic methods. Dependency (variable D) refers to the type and extent of coordination required between the various resources in the production process. When the activities and resources merely contained by the same organisation and only remotely dependent on each other, the dependency is called 'pooled'. When one activity is dependent on a preceding one, the dependency is sequential. When the preceding activity is not only influencing the following activity but also vice versa, the dependency is called 'reciprocal'.

To the four variables (demand variability, co-production, technology, dependency) we have identified so far, we add two more: the input variability (variable E) and the informational nature of the products and services (variable F). These two are important in characterising the 'newer' application domains of Lean Six Sigma such as healthcare and higher education. Input variability signifies the variance between the characteristics of the input units. An input unit can be a material resource but also a patient or a student. The informational nature of a product or service and its process of consumption are designated by the intangible aspects of a product or service. It covers the interaction between the user and the product or service. It is often instructional in nature 'how to …' when combined with a physical product. An engineer-to-order gas treatment system for a liquid natural gas (lng) tanker contains important information with regard to both installation in the tanker and the operations thereof. Training (a transfer of knowledge and capabilities that is predominantly informational in nature) is an essential element of the whole product without which it is useless. With services the information constitutes often the core. So typically a service is mostly informational in nature. A consultancy is a service accompanied by a tangible report but mostly informational. Psychotherapy is (almost exclusively) intangible and informational in nature but possibly with some written questionnaires and perhaps some pharmaceuticals.

Organisations operate in varying environments, with varying technologies. The six variables we identified in this section will help to characterise differences in domains in which Lean Six Sigma is applied.

3 Six variables indicating structural differences in domains

In the preceding section we identified six variables that together comprise a framework we can use to assess structural differences in domains. In this section we describe the variables of the analysis framework in more detail and illustrate them by using them to characterise three very different domains.

3.1 Six variables of an analysis framework

Each domain has its own characteristics. Some of those it shares with other domains, others set it apart. Together they uniquely characterise a domain. The six variables are:

- Output and demand variability
- Co-production
- Interdependency
- Technology
- Input variation
- Informational nature.

Output and demand variation

Output and demand variability refers to the variability in demand with regard to quantity, type and specification of the output, i.e., the products and services. Output quantity can be stable or vary strongly either with or without patterns. Some products are in demand according to a stable, regular pattern and in high quantities and little variation in specification. These are the typical mass produced consumer goods. On the other end are the engineer-to-order, customer-specific products that are very different in the specification and the demand for which can vary strongly and is hard to predict. These are the typically low volume high variety industrial products and specific customer services.

Co-production

Co-production refers to the extent in which the customer has a large contribution (input) in the actual production of the good or service. The production process can be part of the actual product or service. On the one hand we find standard products that are just consumed as-is after they have been produced. On the other hand are services in which supplier and consumer work actively together in producing the output. The service cannot be rendered without the participation of the consumer and the production process is part of the service. Psychotherapy would be an example of such a service. This kind of services is often but not necessarily contemporaneously produced and consumed, and mostly intangible.

Interdependence

Various parts of an organisation are interdependent. Thompson (2003) distinguishes three types of interdependence:

- pooled
- sequential
- reciprocal.

In the instance of pooled dependence, parts of the organisation are not necessarily interacting but nonetheless require (every) other part to make its contribution for the organisation and each to be successful. In the case of sequential dependence, the order and direction of the interdependence are specific. It is asymmetrical in that one requires input of another part. This type of interdependence encompasses the previous type in that neither part can be successful if the other does not perform. The most complex type of interdependence is constituted by reciprocal interdependence in which the involved parts of the organisation need each other to complete the working. Reciprocal encompasses sequential interdependence but this time there exists a sequence of interdependent activities that work one way and the other way around, and so on.

This is important in the context of our framework because "…the three types of interdependence are increasingly difficult to coordinate because they contain increasing degrees of contingencies" (Thompson, 2003, p.55).

Technology

Technology refers to the method by which the product or service is rendered/produced. Though we tend to think of technology as tangible, technical matter, in the sense in which it is used here, a teaching pedagogy, is also a technology. Technology has two dimensions that are important in the context of this paper:

- linkage (Thompson, 2003, pp.15–18)
- predictability.

a Linkage refers to technology that is either

- long-linked – interdependent activities applying (parts) of a technology – mass production assembly lines are a typical example
- mediating – technology linking groups of customers requiring different but complementary services – insurance and banking business are typical examples
- intensive – multiple techniques applied in various configurations according to the feedback from the customer and or object – therapy and construction are typical examples.

Of interest is the extent in which the technology increases the complexity of the organisation and processes. Mediating technology largely separates the workings of two processes and customers with one interface remaining. In the case of the saving and lending, the bank mediates and effectively separates the two groups and activities. In long-linked technology the technology is distributed across activities that are dependent. The complexity is larger than with mediating technology. Intensive technology is more complex still because of reciprocal dependencies. The choice of technology is in part dependent on its effect and the response of the product, patient, student. This feedback loop causes greater degrees of contingency and poses stronger restraints on the workings of the organisation.

b Predictability refers to the extent in which the outcome of the process where the technology is applied can be reliably predicted. And whether any uncertainty is definable in individual instances.

Input variation

The production process input can vary in quantity and specification. The extent in which the input is constant and homogeneous is a source contingency that creates uncertainty. It poses a larger burden on the technology and organisation processing the input. It requires greater flexibility both in capacity and robustness in dealing with variation. An university or a hospital is typically dealing with high input variation. Patients vary in their sex, ages, physical and mental state, their conditions can contain one but also multiple, compounding afflictions. Traditional chemical industry on the other hand deals with fairly well controlled resources as input to its processes. The input variation is consequently much lower than in a hospital.

Informational nature

Information is ambiguous in nature in varying degrees. Information itself is a 'multifaceted, polyvalent concept' (Floridi, 2004, p.40). Any reference, any designation is thereby likely to be multifaceted, polyvalent and thus ambiguous. Information expressed in logical and mathematical formulae is often more precise than spoken, conversational language. Products and services are rarely exclusively informational or material in nature. Most services have physical components and most material products require some information for its use. The larger the informational content of the product or service the larger the uncertainty c.p. Information in as far as it is intended for communication with human agents is more ambiguous than material. The colour 'red' is a less certain qualifier than the wave length of 650 nm. Of course for some purposes information exchange is more useful than material exchange. Handing over a specification is in some cases more instructive than handing over the material. But in essence the object contains more information than the words written, spoken or otherwise, describing the object. As such language mediated information increases uncertainty.

Each of these variables is a source of varying contingencies and constraints. With the contingencies and constraints come uncertainties. As it is one of the goals of an organisation and particularly of operations management to deal with contingencies and constraints, our analysis framework helps to determine the challenges that an operations management strategy must answer. In dealing with these challenges the operations management strategy deploys various concepts and tools. These concepts and tools might (will) need tailoring to be fit for purpose. If we characterise the different domains through our framework, we might find significant differences that require adaptations of the Lean Six Sigma theory and techniques used. If this is the case it might explain why Lean Six Sigma as an operations management strategy is more or less successful in various domains when applied as-is. It might also, we hope, indicate adaptations in the Lean Six Sigma theory that will make it more suitable for the various domains.

3.2 An illustration: using the framework to characterise specific domains

Using these six variables we can characterise different domains. To illustrate the intended use of our framework we take three examples: psychotherapy provided in a mental hospital, speeding ticket processing by ministry of justice and gas treatment equipment for liquid natural gas (lng) tankers.

Example 1: Psychotherapy is both a domain and a technology used to address mental problems that manifest themselves in such a way that it substantially hinders a normal and adequate living on part of the patient. The technology, i.e., the therapy, is multifaceted and have varied, different techniques that can be used (variable D – intensive technology). Therapy can be provided in individual and group settings, in open and closed facilities, with high and low frequency of sessions. The effectiveness of the therapy is hard to predict in individual cases. Patients can suffer multiple mental and physical disorders (variable E – strong input variation). At the level of the institution the demand for help varies in the short run considerably, in the long run it is fairly predictable (variable A – demand variation). Though the unforeseen economic crisis of 2008 and subsequent years has caused a substantial increase in demand. The patient plays a crucial role in both the treatment and its effect. The patient and the therapist are reciprocally interdependent in applying the therapy (variable B – co-production).

Example 2: Law enforcement agencies place cameras along highways to electronically and automatically measure the speed of passing cars. The measurement itself is not completely accurate but has a known deviation. The measurement is corrected for that deviation (variable E – limited input variation). The same goes for the identification of the license plate. Not 100% fail-save but with human corrections in case of doubt it is considered reliable. Most pictures of transgressors are processed automatically. The legal code is clearly defined and the applicable fines are calculated automatically (variable C – long-linked technology). Notifications are generated automatically. The steps in the process are sequentially interdependent. The output fluctuates little except when special campaigns are launched (variable A – limited demand variation). Most drivers are at best unwilling participants in this process and cannot be said to be actively involved in or exposed to the process (variable B – no co-production here).

Example 3: Liquid natural gas is transported with special bulk carriers in which the gas is stored in liquefied state. During storage chemical processes create gasses that are dangerous and need to be removed before tanks can be inspected or repaired. Special installations are created to 'wash' or remove the gasses, to process them so that they can be safely deposited. These installations are custom designed taking into account the design of the carrier (for mechanical and construction purposes as well as for chemical purposes), the capacity of carrier, its sea routes (as the installation uses sea water which varies in temperature, salinity, etc.) all which influence the treatment processes (variable A – high demand variation with regard to specification). Engineers of the yard building the carrier and the installation designing engineers work closely together to create the best fit (variable B – intensive co-production). The demand for carriers and hence for the installation varies with geo-political situation in the world, it is a global market (variable A – moderate to strong demand variation). The process of washing is well known and can be controlled and predicted very well (variable C – long-linked technology with sequential dependency).

4 Characterising Lean Six Sigma for higher education

Using our framework we now try to identify some defining aspects of Lean Six Sigma for higher education. This is the initial and main aim of our research. It provides us with some initial assessments of the fitness for purpose of Lean Six Sigma for higher education.

4.1 Output and demand variability

Universities face fluctuations in demands as economic trends and job markets change. Both the number of students and studies they enrol in vary. Seasonal patterns are well known and fixed mostly by law and regulations offering students mostly a few times a year to enrol. Once enrolled the demand in following years of enrolment is fairly well known and can be monitored by universities quite well. So demand variability decreases as a cohort of students progresses through university. The output qualifications are relatively straightforward and determined to some extent at the (inter)national level already. In Europe, for example, the Dublin descriptors define the end terms that all higher education must reach.

4.2 Co-production

Students are an integral part of the education process. As such they are exposed to the internal workings of a substantial number of the educational processes, though not all. But not only is the student exposed to the internal workings of the processes, he or she is a co-producer of the outcome. Through exercises, study, projects and assignments, through classroom attendance and dialogue, students together with fellow students and lecturer jointly 'produce' knowledgeable graduates.

4.3 Interdependency

Classes and courses refer to each other and are dependent on both quality, content and intangible things such as atmosphere. If particular concepts are not, or not well explained in preceding courses, the current course will suffer in effectiveness. Likewise the quality of supportive processes impacts the student satisfaction which in turn has an effect on the attitude of a student during the course. In particular in multi-lecturer courses, there is a reciprocal dependency on various processes and process steps. The quality of one lecturer's teaching directly effects the teaching of another and vice versa. Examination and teaching constitute yet another example of the strong interdependency in educational processes. The teaching is geared towards the examination and the examination is focused around the teaching. Particular results in mid-term examinations might trigger changes in the teaching methods. The design and teaching methods in following years are also in part influenced by the examination results as far as they are input for a continuous improvement cycle.

4.4 Technology

Classroom as the main, almost exclusive modus of transferring knowledge is long gone. It still plays a dominant role though decreasingly so. Teaching involves various pedagogical methods (in this context also called techniques which together form the technology of education) including group and individual assignments with peer reviews as both a grading and a learning method. Blended learning, flipped classroom and massive open online courses are recent additions to a wide range of techniques used in universities. Both in the design of courses and depending on student feedback, various techniques are deployed. The effectiveness of varying techniques depends not only on the course design but also on the response from students. Depending on the response the techniques deployed can also be changed. Hence the qualification of intensive technology is applied to the domain of higher education. An example is the situation in which through both self-study and classroom lecture a particular theory is explained. If through student questions or a mid-term examination it becomes clear that the theory is not well understood, the lecturer might chose to elucidate the theory by means of exercises, a field trip or experiment. If on the other had the theory has been understood well, the lecturer might chose to add some additional challenges.

4.5 Input variation

Students come with different backgrounds (former high school education, family situation, etc.), different sex (boys and girls have markedly different study preferences and respond differently to the ways information is presented), different ambitions, preferred learning style, prior knowledge, social skills, etc. All these variables cause a high degree of variation in input. The variation in input is to some degree lessened through entry conditions, formal selection procedures and informal selection. Nonetheless input variation is considerable especially when compared to industry or even financial services.

4.6 Informational nature

Finally, teaching is a predominantly information-oriented activity. Information is sometimes fuzzy and ambiguous. What the teacher exactly said and meant, what the student was actually asking about something he/she did not understand, etc. is at times not strictly defined and clear. Meanings of words might change in different contexts even within a course. Examination criteria are an example in case. Both the criteria themselves and the extent in which an assignment meets them are a topic of frequent debate between student and lecturer, and amongst lecturers.

Each of these variables also interacts with each other and increases the effect of one another. Having a varied student population from different social and regional background with each different habits and dialects increases the uncertainty of information. It also has an impact on the effectiveness of the techniques used in teaching. Have the students been previously exposed to particular Internet technology or not, to what extent have they been trained in independent assignment work, how do they approach the required readings, etc. The stronger the student participation in the process, the more important information becomes to coordinate the various tasks in the process. It is easy to see how the six variables depend on each other and create a complex web of interdependencies. A detailed description of the relationships between the six variables is outside the scope of this paper, but will need attention to better understand the impact of each element on Lean Six Sigma practices.

5 Adjustment of Lean Six Sigma concepts based on the profile of a domain

We think it would be naïve to assume that the same Lean Six Sigma theory and techniques apply to education as to mass production without any further adjustment. Compare the description of education in the previous section with the production of an automobile. A car for one thing does not talk back, many of its inputs are well controlled, the process steps are mostly sequentially interdependent and the informational content of the product is much less. The complexity and dynamics are therefore of a different order.

Though there is a prima facie case for the application of Lean Six Sigma to HE, there is also a prima facie case for adjustment. The lack of success so far might have to do a lot with the lack of change management skill but also probably with structural differences in the domain. This is a proposition that deserves at least consideration based on the analysis provided in this paper. The contingencies that an organisation faces determine in part the way it is organised. And more importantly for our current purposes it determines the operations management strategies: the way Lean Six Sigma is applied and what concepts and tools can be and are used. Given that Lean Six Sigma has been developed in and for a rather specific situation implies that new application domains might require a different and/or adapted set of concepts and tools.

Consider the following examples. One. Organisations that face a high degree of variation in demand with small quantities will have trouble implementing Lean Six Sigma concepts such as takt and Kanban (Suri, 1998). The takt time would require constant recalculation and thereby losing its usefulness. Having many different products often requires seldom used parts for which having a Kanban card makes little sense. Rather than have products as the unit of measurement, it is better off having work content as its unit of measurement. The use of Polca card instead of Kanban cards might be more appropriate. The traditional Lean Six Sigma approach of demand levelling might be inappropriate if the fluctuations and ability to meet them are of strategic importance to an organisation. Two. In analysing value streams of products that have a strong informational character, the traditional value stream maps will hardly suffice. Though conceived as material and information flow analysis, the actual expressiveness is low when it comes to the modelling of information and information flow. A case study by Brouwer-Hadzialic and Wiegel (2014) clearly demonstrates how some traditional Lean Six Sigma tools do not work well in the context of higher education. The value stream mapping technique in particular is demonstrated to be of too little expressiveness to suffice for the analysis of the information flow in higher education. The information flow is rather varied. It includes both process steering information and information as part of the service itself. The types of information are manifold and refer to exams, assignments, project, schedules, literature, groupings, etc. The information can be repetitive and one-off, from one lecturer to one student or all students, from all lecturers to all students. The type of swimming lanes suggested by Wiegand and Franck (2005) for administration would offer a better alternative. And service blue printing (Bitner et al., 2007) might offer a more expressive technique still. In a similar vein Bateman et al. (2014) makes a convincing case for some adaptations of the traditional five Lean principles when applying Lean to military organisations. The nature of maintenance work, the hierarchical organisational structure and some other factors explain why for example the traditional version of the pull principle does not makes sense in low volume, unpredictable maintenance work. It can be salvaged but with some adaptations.

6 Conclusions and future research

The domain of higher education is faced with serious challenges on quality and cost. It is thus that educational institutes turn to improvement approaches such as Lean Six Sigma. It has proven effective in various domains such as industry. Applying Lean Six Sigma in HE has yielded some effects but clearly less than expected. This lack of success has been attributed to lack of general and change management capabilities. Though plausible we argued that there are structural differences in the domain of higher education. The differences are described by six variables:

- output and demand variability
- co-production
- interdependency
- technology
- input variation
- informational nature.

We presented a framework that describes domains in terms of these six variables. Differences in turn have an impact on the applicability of various Lean Six Sigma theory and techniques. These differences make an as-is application of Lean Six Sigma less plausible. Ours is an initial argument to look closer into adaptation of Lean Six Sigma when applying it to different domains than those in which and for which it was originally developed.

More detailed attention needs to be paid to the impact of the variables to the Lean Six Sigma theory and techniques. Which concepts and tools are impacted and how exactly? A second aspect that requires further research is the relationship between the variables. How do they influence, strengthen or weaken each other? What also remains unclear is the characterisation of the degree of (un)certainty caused by the six variables. Finally, the case of higher education has been described very tentatively and merits more extensive description. Especially now Lean Six Sigma for higher education seems to be gathering more attention of Lean Six Sigma practitioners and researchers.

There is a prima facie case for the application of Lean Six Sigma to higher education and other new domains outside high volume, repetitive production. Applying Lean Six Sigma as-is, however, is naïve and likely to decrease its effectiveness.

References

Antony, J., Krishan, N., Cullen, D. and Kumar, M. (2012) 'Lean Six Sigma for Higher Education institutions (HEIs): Challenges, barriers, success factors, tools/techniques', *International Journal of Productivity and Performance Management*, Vol. 61, No. 8, pp.940–948.

Balzer, W.K. (2010) *Lean Higher Education: Increasing the Value and Performance of University Processes*, Productivity Press, New York.

Bateman, N., Hines, P. and Davidson, P. (2014) 'Wider applications for lean: an examination of the fundamental principles within public sector organisations', *International Journal of Productivity and Performance Management*, Vol. 63, No. 5, pp.550–568.

Bitner, M.J., Ostrom, A.L. and Morgan, F.N. (2007) 'Service blueprinting: a practical technique for service innovation', *California Management Review*, pp.66–94.

Brouwer-Hadzialic, L. and Wiegel, V. (2014) 'Case study: using value stream mapping in educational process', Paper presented at the *2nd International LeanSixSigma for Higher Education Conference*, The Netherlands, 2–4 June, 2014.

Emiliani, M.L. (2004) 'Improving business school courses by applying lean principles and practices', *Quality Assurance in Education*, Vol. 12, No. 4, pp.175–187.

Floridi, L. (Ed.) (2004) *Philosophy of Information*, Blackwell Publishing, Malden.

Mazzocato, P., Savage, C., Brommels, M., Aronsson, H. and Thor, J. (2010) 'Lean thinking in healthcare: a realist review of the literature', *Quality and Safety in Health Care*, Published online 19 August, 2010.

Ostrom, E. (1996) 'Crossing the great divide: coproduction, synergy and development', *World Development*, Vol. 24, No. 6, pp.1073–1087.

Radnor, Z. and Osborne, S.P. (2013) 'Lean: a failed theory for public services?', *Public Management Review*, Vol. 15, No. 2, pp.265–287.

Radnor, Z., Osborne, S.P., Kinder, T. and Mutton, J. (2014) 'Operationalizing co-production in public services delivery the contribution of service blueprinting', *Public Management Review*, Vol. 16, No. 3.

Slack, N., Chambers S. and Johnston R., (2010) *Operations Management*, 6th ed., Pearson Education, Harlow.

Suri, R. (1998) *Quick Response Manufacturing: A Companywide Approach to Reducing Lead Times*, Productivity Press, New York.

Thompson, J.D. (2003) *Organizations in Action: Social Science Bases of Administrative Theory*, Transaction Publishers, New Brunswick NJ.

Wiegand, B. and Franck, P. (2005) 'Lean administration: analysis: how to make business processes transparent', *Workbook for Managers and Employees in Industry, Administration and the Service Sector*, Vols. 1–2, Lean Management Institute.

Website

MIT Sloan Management [online], http://mitsloan.mit.edu/omg/om-definition.php (Accessed 21 October, 2014).

Notes

[1]We refer to LeanSixSigma as a theory which encompasses concepts, methods and techniques but also underlying principles. In our view LeanSixSigma is more than a set of tools and techniques that might need tweaking. At a more fundamental, theoretical level reconsideration might be called for.

[2]There are many different definitions of co-production. See for example, Ostrom (1996), Bitner et al. (2007). For our current purposes the loose definition suffices. We merely want to identify variables that describe structural differences in domains. For a more detailed analysis of the impact of the variables a more precise definition will be called for.

Bibliography

Barosso, I.P.M., Santos, S.M.F. and Carravilla, M.A. (2010) 'Beyond classroom boundaries: how higher education institutions apply lean', *1st Brazilian Symposium on Services Science*, Brasilia, 17–19 November, 2010.

Comm, C.L. and Mathaisel, D.F.X. (2003) 'Less is more: a framework for a sustainable university', *International Journal of Sustainability in Higher Education*, Vol. 4, No. 4, pp.314–323.

Hines, P. and Lethbridge, S. (2008) 'New development: creating a lean university', *Public Money & Management*, Vol. 28, No. 1, February, pp.53–56.

Larsson, R. and Bowen, D.E. (1989) 'Organization and customer: managing design and coordination of services', *Academy of Management Review*, Vol. 14, No. 2, pp.213–233.

Sanders, N. (2014) *The Definitive Guide to Manufacturing and Service Operations*, Pearson Education, Upper Saddle River, NJ.

Scott, R.W. (2008) *Introduction to the Transaction Edition: Thompson's Bridge over Troubled Waters*, Transaction Publishers, New Brunswick NJ.

Slomp, J. (2012) *Sequential Dependency*, Inaugural Speech, HAN University of Applied Sciences.