INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN BUSINESS & SOCIAL SCIENCES

Vol 13, Issue 10, (2023) E-ISSN: 2222-6990

The Fundamental Concept of Integrates Lean Six Sigma and DMADV Methodologies

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To Link this Article: http://dx.doi.org/10.6007/IJARBSS/v13-i10/18960 DOI:10.6007/IJARBSS/v13-i10/18960

Published Date: *25 October, 2023*

Abstract

Present economic conflicts increase the continues demand for lucrative results that let companies to increase competitive benefit. For this purpose, more establishments look for organizational practices that permit them to enhance their service and/or products features, flawless their procedures, reduce expenses, strengthen the assets productivity and client's gratification. This have been verified through Lean practices and Six Sigma joined methods in their management and manufacture methods in which, Lean attention mostly on the elimination of waste or non-value added process, and Six Sigma on the control and management of process consistency. The integration of Lean and Six Sigma, which is Lean Six Sigma (LSS) is a systematic approach to decrease or eliminate non-value-added process and optimize process variation. The implementation of LSS is laid on 2 fundamental methodologies, the "Define, Measure, Analyze, Improve, Control" (DMAIC) methodology which focuses on process improvement, and the "Define, Measure, Analyze, Design, Verify" (DMADV) methodology for new process invention. Finding from empirical review reveal that prior studies on LSS to view DMAIC and DMADV practices separately. the concept of how DMAIC and DMADV could be integrated for process improvement and new process invention are remains ambiguous. Hence, this paper aims to review the literature of DMAIC and DMADV with the objective to propose the fundamental concept of integrating both DMAIC and DMADV approach into one standard process improvement and invention methodology.

Keywords: Lean, Six Sigma, Lean Six sigma, DMAIC, DMADV

Introduction

Lean Six Sigma integrates different approaches for business development whether it be in the service or industrial sectors to maximize levels of customer satisfaction in the opposing market for the organization. Customers assume on-time delivery of their anticipated products without added costs for quality (Seth, Seth, and Dhariwal 2017). Every company is struggling for the cost saving by reducing variations or defects in the processes and products to gain better bottom-line outcome than their rivals. To overcome such challenges, manufacturing firms strive to develop creative procedures and/or other quality development

techniques to provide value to clients. LSS is a commonly used experienced method that renders the developments in the quality of goods. It is a methodology driven by data that facilitates enhanced business performance by reducing waste, removing non-value-added actions and reducing process differences (Trehan, Gupta, and Handa 2019), to accomplish operative excellence at a cost reduced (Seth et al. 2017). Finding from empirical review suggested that there are 2 common approaches for LSS implementation, which are the Define, Measure, Analyze, Improve, Control (DMAIC) approach, and the Define, Measure, Analyze, Design, Verify (DMADV) approach. DMAIC approach is commonly used for process improvement, while DMADV for invention of new process. Empirical research found that prior studies on LSS tends to focus on exploring and confirming the best practices for DMAIC and DMADV separately as well as comparing the differences between DMAIC and DMADV. However, the concept of how DMAIC and DMADV could be integrated for process improvement and new process invention are remains ambiguous. Based on the principle of Lean, which stresses on the elimination of non-value-added process, the researcher argue that process improvement and invention via two different methodologies (i.e. DMAIC and DMADV) is a non-value-added process. Instead, process improvement and invention should be carried out under a universal methodology. Hence, this paper aims to review the literature of DMAIC and DMADV with the objective to propose the fundamental concept of integrating both DMAIC and DMADV approach into one standard process improvement and invention methodology.

Literature Review

This paper will refer to literature reviews of prior studies and researches published on topics related to lean six sigma methodology and LSS practices with respect to DMADV and DMAIC.

Lean and Six Sigma

Recently, Lean and Six Sigma (LSS) have become the most common business approaches for applying continuous improvement (CI) in production, public sectors, and service. CI became the main target for many firms around the world to assist them to accomplish operational and quality goals and to improve position (Saja, Jiju, and Lim 2015).

Applying Six Sigma alone cannot eliminate all waste types from process, and applying Lean management alone statistically cannot control the process and eliminate deviations (Corbett, 2011). Hence, number of corporations have agreed to combine both methods to eliminate the weaknesses of these two CI methodologies when they are applied separately, also to find a greater plan for CI and improving processes Bhuiyan et al. (2006).

Lean Six Sigma was acknowledged by (Antony, Snee, and Hoerl 2017) as a business approach and procedure that improve development performance ensuing in improved buyer satisfaction and enhanced bottom line outcomes. LSS methodology purposes to enhance ability in a company, decrease costs of production and increase investors value by increasing quality (Alessandro Laureani and Jiju Antony 2012). A case studies review has recognized many objects for organizations to apply LSS strategy in the new era: as an example, to improve operational efficiency and performance of their business, especially in the rapid development of worldwide marketplaces, to increase quality of products (Vinodh et al. 2014), reduce production costs and enhance customer satisfaction.

Benefits of LSS in industrial sector has resulted in more than 50 benefits are identified from 19 case studies (Saja et al. 2015). The top ten are:

(1) improved profits and financial investments;
(2) increase satisfaction of customers;
(3) cost reduction;
(4) reduced time cycle;
(5) key performance statics are improved;
(6) less defects;
(7) reduction in time of machine breakdown;
(8) less inventory;
(9) better quality; and
(10) increase capacity of production.

Six Sigma approach is a more organized than Lean. Two significant frameworks Six Sigma has, DMADV and DMAIC, both are orderly from perspective of application. The experts get simplicity on phase-wise outcomes in Six Sigma. Lean depends on value mapping, identification of waste, techniques flow, etc. not all are sequential, and can be implemented in parallel. Yet, lean, six sigma, and lean six sigma shares the same goal which is improvement of production and organizational performance. discussing LSS is important in this paper to understand its effect on organization performance. Based on the literature review above, Table 1 summarized previous research on Lean, Six Sigma, LSS, and organization performance.

Table 1:
Prior Studies and Findings on LSS

	Research	Finding
1	Assarlind et al., 2012	LSS is a continuous improvement tool that enhanced organization performance
2	Snee (2010)	LSS is a business methodology and strategy which increases procedure act resulting in greater customer satisfaction and improved results ofvbottom line.
3	Saja et al., 2015	LSS is the most known business strategies for continues improvement and achieve operational excellence
4	Womack et al. (1990)	defined Lean as a "dynamic process of change aimed at continuous improvement."
5	Yamamoto et al., 2019	Lean manufacturing aims to make what adds value apparent by eliminating everything else
6	Drohomeretski et al. (2014)	Lean concentration is on reducing total time cycle
7	Antony (2008)	Six sigma is an method that aims to recognize and remove defects, failures or mistakes in business developments
8	Kujawa (2006)	An effective methodology Six Sigma is for creating and sustaining long-term goals and competitive advantage
9	Tjahjono et al. (2010)	Six Sigma – a set of tools of statistics, a management operational philosophy , a professional culture and an analysis methodology that uses the logical methods.
10	Vijaya Sunder, 2015	Six Sigma, shown to be effective in service areas like public sector, financial services, education, banking, information technology and health care
11	Antony et al., 2017	LSS is a business methodology and strategy that aim to increase performance of process leading to improved clients satisfaction and better results of bottom line
12	Laureani and Antony, 2012	LSS practices aim to increase capability in an organization, minimize costs of manufacture and increase the value for owners by quality improving
13	Vinodh et al., 2012	organizations implement LSS strategy to improve their operational efficiency and business performance
14	Albliwi et al., 2015	Listed top 5 motivation reasons to implement LSS in industrial companies

According to Table 1, previous researchers viewed LSS from different perspectives. Assarlind et. al. 2012 and Womack et al. (1990) viewed LSS as tool for continuous improvement, while Snee (2010), Vinodh et al., 2012, Antony et al., 2017 regarded LSS as business strategy. Additionally, Vijaya Sunder, 2015 proved that LSS can be successfully implemented in services rather than production industries. However, all of the researchers share a common view that LSS enhance organization performance.

In this paper, LSS is viewed as process for improving organization performance because of its practices the DMAIC and DMADV. They all are sequence of practices leading to enhancing performance and better outcome. This is in line with this paper objective which is to examine LSS practices and discuss literature review findings on LSS DMADV and DMAIC.

Common practices of Lean Six Sigma

Research leanings show that application of Six Sigma practices begins with factors of integration. This increases process effectiveness of Continues Improvement that is based on unique features of the issue required to be solved. In general, there are two main categories of incorporation structures of the Six Sigma practices existing in the literature discussed earlier. The first category offers the alignment of the Six Sigma method with other general CI practices, like Lean, which shaped the common term of "Lean Six Sigma". The second category related to specific tools usage for analysis or practices in DMADV or DMAIC steps. These specific tools are applied precisely to develop the usefulness of the analysis at any steps of the DMADV or DMAIC (Purushothaman and Ahmad 2022).

LSS methodology based on two implementations stages to direct the process of continues improvement. The steps are Define, Measure, Analyse, Design, Verify (DMADV), and Define, Measure, Analyze, Improve, Control (DMAIC) . The DMAIC approach are usually applied to explain problems that are connected to "process-improvement". For instance, (Hakimi et al. (2018) improved production quality of plain yogurt processes by implementing DMAIC steps. The design of experiment (DOE) was used to recognize the process limitations that led to product defects, and thus, the ideal setting required of main process limitations to solve product quality problem of was resolute. Recently, more cases presented of DMAIC application steps addressed by(Khan, Badar, and Alzaabi 2020), (Patyal, Modgil, and Koilakuntla 2021), (Kumar, Singh, and Bhamu 2021) and (Hardy, Kundu, and Latif 2021). Meanwhile and on the other hand, the DMADV scheme or approach is regularly referred to when applying new plans because of its based on data, its method and ability to identify success earlier , which requires detailed examination (Trubetskaya, Mcdermott, and Ryan 2023).

Studies by prior scholars on LSS main practices DMAIC and DMADV perspective

In the present time of digitization and open markets, customer buys from an enormous varieties of existing retailing points. Customer satisfaction and focus still moving organizations to improvement of quality; product or service should be paid for the real value by customer; hence, the customer is not willing to tolerate any obligation to pay or value for any mishandling or rework happened during dispensation even for non-value added actions (Abu et al. 2019). Lean six sigma method, under the concept of total quality management (TQM), works on ideologies of client attracting, concerned with process, data-driven procedures and breakthrough enhancement approach (Araman and Saleh 2022). The DMAIC method in Six Sigma is often defined as an approach for solving problems (De Mast & Lokkerbol, 2012). Six sigma – DMAIC method works on linking customer needs and the business alongside for the advantage of CI approach (Tampubolon and Purba 2021). DMAIC method is relevant with both manufacturing industries and services, while, in industrial businesses, the helpful effect of deploying LSS is faster and greater than in services (Trimarjoko, Purba, and Nindiani 2020). The reason is the complications of measuring and evaluating of apparent customer satisfaction and quality in situation of services (Munteanu 2017). Many stories around the globe of success in industrial businesses credited to the application of LSS, for example, Ingersoll Rand succeed from applying DMAIC approach and six sigma practices which resulted in defects minimizing to 70% and enhanced the sigma level from 0.5 to 3.53 which effected customer gratification enormously (Araman and Saleh 2022). Pugna et al. (2016) used DMAIC Six Sigma with statistical practices such as Pareto charts, control chart etc. to improve the assembly procedure in an automotive industry in Romania.

Swarnakar and Vinodh (2016) established a framework, in which applied DMAIC methodology with Lean tools that enables removal of non-value added processes to improve lowest line outcomes. The framework was verified by deploying it in manufacture line of an automotive part production business. Ben Ruben et al. (2017) described LSS context by bearing in mind environmental effects of manufacture processes and the framework was tested through a case study made in Indian automotive firm. A significant drop in internal defects was noticed. This was an effectual initiative to rise sigma level along with minimizing environmental influence. Deeb et al. (2018) introduced a general context concerning implementation of Six Sigma in small and medium enterprises. The planned context was recognized by meta-model and identified the needs of each stage of the DMAIC method (Kumar et al. 2021).

Some of former studies apply DMAIC six sigma in developing the activities of manufacture control and planning systems. For example, Chang et al. (2012) applied six sigma for enhancing the performance of planning procedures and production control in a firm. The analysis showed that such kind of performance development can be accomplished by information systems integration. Additional study was made by Antony et al. (2012) presented a case study on implementing DMAIC six sigma method in a factory that assembles automotive products. The approach outcome resulted in minimizing the tolerance related complications and improving the first pass revenue by approximately 17% and about US$70,000 savings per year.

Panayiotou et al. (2022) studied the adoption of LSS methodology in SMEs in Greece. A case study on implementing DMAIC with Yin's methods was illustrated. The findings showed that to effectively benefit from the LSS, utilization of employee working hours is critical. Also, they noticed that the effect of LSS can be measured by non-monetary measures that can be ultimately translated into monetary measures. Another LSS study by Sánchez-Rebull et al. (2020) was implemented in a large German food can production company. Important savings in the company could be accomplished and therefore, bank crediting is not required anymore as cash flow deficits were removed. One more study by Rifqi et al. (2021) implemented LSS in the agribusiness by taking a plant for cookie manufacturing as case study in a Moroccan SME. Scrap can be minimized by 6% and operational effectiveness can be improved by 5.6% (Araman and Saleh 2022).

Based on the literature overview of studies discussed in aforementioned paragraphs, a finding which is related to the scope of existing research project is highlighted. It was founded that many of the available articles focus on continues improvement through DMAIC and less focus on DMADV. Therefore, this is the first finding of this paper that from previous scholars have conducted more researches and studies on DMAIC than can be found on DMADV. This could represent a knowledge gap that requires a comprehensive study to understand the benefits and possibilities open to operation by applying DMADV. The following table 2 summarize prior studies of those who have done research on DMAIC and others on DMADV and the overall result support this finding. Discovering this gab is very important to encourage academics to do more work on DMADV for a better understanding for all the possible practices which can lead to a better organizational performance.

Table 2
Prior scholars on DMAIC & DMADV

#	Scholars	D	M	A	I	C	D	V
1	Hakimi et al., 2018	✓	✓	✓	✓	✓		
2	Khan et al. 2020	✓	✓	✓	✓	✓		
3	Patyal et al., 2021	✓	✓	✓	✓	✓		
4	Kumar et al., 2021	✓	✓	✓	✓	✓		
5	Hardy et al., 2021	✓	✓	✓	✓	✓		
6	Tenera & Pinto, 2014	✓	✓	✓	✓	✓		
7	De Mast & Lokkerbol, 2012	✓	✓	✓	✓	✓		
8	Tampubolon and Purba, 2021	✓	✓	✓	✓	✓		
9	Tarimarjoko et al., 2020	✓	✓	✓	✓	✓		
10	Munteanu, 2017	✓	✓	✓	✓	✓		
11	Araman & Saleh, 2022	✓	✓	✓	✓	✓		
12	Pugna et al. 2016	✓	✓	✓	✓	✓		
13	Swarnakar and Vinodh 2016	✓	✓	✓	✓	✓		
14	Ben Ruben et al. 2017	✓	✓	✓	✓	✓		
15	Chang et al. 2012	✓	✓	✓	✓	✓		
16	Antony et al. 2012	✓	✓	✓	✓	✓		
17	Panayiotou et al. 2021	✓	✓	✓	✓	✓		
18	Trubetskaya et al., 2023	✓	✓	✓			✓	✓
19	Burke and Silvestrini, 2017	✓	✓	✓			✓	✓
20	Shahrizal (2013a)	✓	✓	✓			✓	✓
21	Long et al. (2011)	✓	✓	✓			✓	✓
22	Huang et al. (2010)	✓	✓	✓			✓	✓
23	Aligula, Kok, and Sim 2017	✓	✓	✓			✓	✓

Nevertheless, many literature discussions uses DMAIC approach to eliminate problems of current process. Define, Measure, Analyze, Design, and Verify (DMADV) is a data-oriented quality plan which emphases on new products or services development compared to current ones (Burke and Silvestrini 2017). The goal of DMADV is to reduce the risk of errors and defects in the manufacturing process. This is done by using a variety of tools and

techniques, including lean manufacturing, and other methods, to ensure that products are designed correctly from the start.

Also, recent researches have stated just how quality improve of service, product and process through design for six sigma (DFSS)/(DMADV) approach could be achieved. Bin Mohd Rafique (2013) discussed a case in which product design time cycle for a wireless access point device was minimized by a quarter by applying DFSS, meanwhile Long et al. (2011) explained how DFSS could be implemented to form "a process for effectively managing IT system changes" within a mid-size IT organization. In addition, (Huang egt al. (2010) discussed a case study where DMADV method was implemented, and enhancement in the "quality of surveillance cameras" was accomplished by minimizing the ratio of defective manual soldering process from 0.89 to 0 (Aligula, Kok, and Sim 2017).

That said, there is a very narrow path in discussing DMADV and its importance in different practices of LSS and most of the studies were conducted on DMAIC. Additionally, DMAIC aims for process improvement while DMADV aims for process breakthrough which can be very effective tool for business improvement.

DMAIC Methodology

DMAIC is used to improve processes a data-driven quality strategy. The letters in the abbreviation represent the five stages that create the procedure, involving the means to be used to finish those stages shown in Figure 1. DMAIC model is a systematic process for improving & analyzing business processes. DMAIC is a data-driven quality approach used to develop processes. It is an important part of a Six Sigma ingenuity, but generally can be applied as a separate quality development procedure or as part of another process enhancement initiatives (Sodhi 2020). five phases It consists of:

1. Define the issue, improve action, chance for enhancement, the project aims, and customer (internal and external) needs (Duarte and Cruz-Machado 2013). Project charter to define the focus, direction, scope , and incentive for the development team.
2. Measure performance of the process (Singh and Sodhi 2014). Create map for writing the activities achieved as part of a procedure.
3. The collected data has to be examined, analyzed and identify the source causes the defects (Selvi and Majumdar 2014).
4. Improve procedure implementation by highlighting and removing the reasons (Sodhi 2020). Create of researches to explain complications from multipart systems or processes where there are many factors could be impacting the results and where it is likely to separate one factor or element from the others.
5. Control phase: The main goal of the last stage of the DMAIC is to create metrics that will assist leaders observe and document continuous success (Selvi and Majumdar 2014).

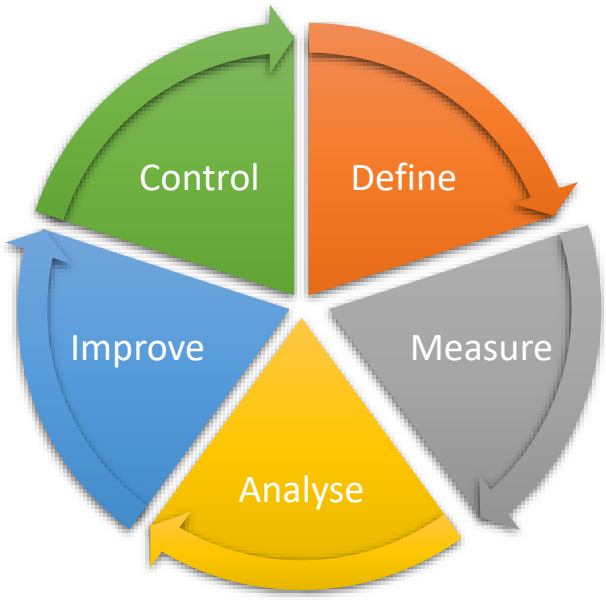

Figure 1: DMAIC Cycle

DMADV Methodology

The DMADV methodology, consist of five phases (Selvi and Majumdar 2014):

1. **Define Phase**

Project holders identify requirements believed to be most important for customers. The requirements are recognized through historical reports, customers opinions and other information sources.

2. **Measure Phase**

The second part of the DMAIC is using the specified metrics to gather information and write specifications and details in a way that could be used to support drive the remaining of the process.

3. **Analyze Phase**

The outcome of manufacturing stage (like finished service or product) is tested by internal groups to create a ground for improvement.

4. **Design Phase**

This phase is known as the process when the desires of customers are reflected into prescriptions for the adjustment and use of systems. An effective design process is described by a cyclic cause of reasoning, in which means and objective, solution and problem are studied in their common interaction (Penney 1995).

5. **Verify Phase**

The last stage in the DMADV methodology is verify face. This phase is used for validating that a service, product, or structure meets its relevant specifications and fulfils its planned purpose. If a requirement is not verifiable directly, requirements at lower-level must be delivered from the top-level requirement until a reasonable verification method can be addressed (Anne-Liza et al. 2022). This phase consist of the following stages (Kumar et al. 2021):

- Verification of customer complaints.
- verification of cost effectiveness.
- verification of tangible benefits.
- verification of intangible benefits.

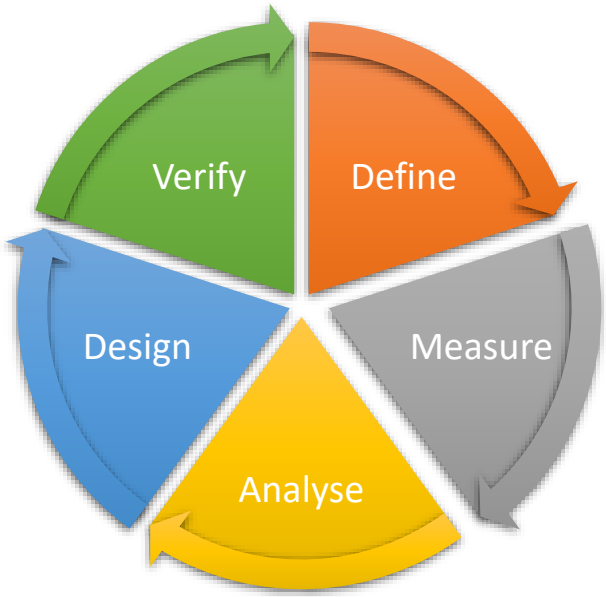

Figure 2: DMADV Cycle

DMAIC Versus DMADV Methodologies

As discussed by prior scholars, DMAIC focuses on improvement of current process. The methodology involves defining business procedures, current performance measuring of a business procedure, outline the main reason of a problem, making developments to the business procedure to decrease faults, and applying controls to notify leaders when the process is out of control. Whereas, DMADV emphases on creating of new process to fulfil customer requirements. The methodology comprises of defining the client's desires, measure customer's desires, discover a process choices that will encounter the customer's needs, creating a business type that helps meet the customer's requirements, and verifying that the new model meets the customer's needs. Relatively, DMADV focuses on meeting customer need via new business model, process or product, hence DMADV approach implies higher impact on the business and organization performance because meeting customer need is the ultimate aim of any business for competitive advantage (Kuncoro and Suriani 2018).

The principle of Lean stresses on the elimination of non-value-added process and the optimization of value-added process. Hence, viewing or implementing process improvement and invention via 2 different methodologies (i.e. DMAIC and DMADV) apparently is against the principle. Instead, process improvement and invention should be applied via a common methodology. Based on the literature review conducted on both DMAIC and DMADV methodologies, the researcher propose 3 fundamental concepts to integrate DMAIC and DMADV methodologies into one common methodology for the improvement for current process as well as invention of new process. The 3 fundamental concepts are as the following:

Concept 1: DMAIC + DV

The first concept is to integrate DMAIC methodology with the Design and Verify phase of DMADC methodology to form a DMAICDC methodology. This methodology is laid on the principle of viewing process improvement as a continuous process, meantime believed that there is a limit for incrementally improvement. Hence, when the improvement of process is

optimized whereby further incrementally improvement is very unlikely, the improvement effect should be focus on inventing a new process. This concept allows a decision to be made on the nature of improvement (i.e. IC or DV) based on the finding from DMA phases.

Concept 2: DMAIC + DMADV

This concept views the integration from the holistic points of view by integrating practices phase by phase. The concept suggests to review the practice phase by phase, explore the commonality and integrate into a single common phase. As an example, the concept required researcher to review what are the practices of Define under DMAIC, as well as the practices of Define under DMADV, subsequently, compare the 2 set of practices for integration. Under this concept, the Improve phase and Design phase will be combined to form a new phase, and the same for the Control and Verify phase. The new methodology developed under this concept views process improvement and invention as common entity and could be implemented together.

Concept 3: DMADV

The third concept views improvement of process should be carried out through invention instead of incrementally improvement. This concept views DMADV process should replace DMAIC as methodology for process improvement and invention.

Conclusion

This paper aimed to review the literature of DMAIC and DMADV with the objective to suggest a definitive concept for integrating both DMAIC and DMADV approaches into one ordinary process as improvement and development methodology. The objective was achieved by suggesting 3 possible concepts to integrate DMADV and DMAIC methodologies into one common method for the development of existing process as well as creation of new process. The 3 fundamental concepts are (DMAIC + DV, DMAIC + DMADV, and DMADV). It is also noticeable that most prior research on LSS commonly agreed that DMAIC is the key improvement driver for organization performance, however the impact of DMADV on organization performance remain unambiguous because there is a lack of rigorous research in the prior literature on DMADV. In closing, the objective for this paper has been achieved.

DMAIC and DMADV methodologies considered two of the most successful and powerful tools for business development and organization performance enhancement. This study extended the theoretical contribution of DMAIC and DMADV by proposed the fundamental concept of integrating both DMAIC and DMADV approach into one standard process improvement and invention methodology. Conducting research in this field is very important to discover, suggest, and investigate a new possible approach(s). The significance and contextual contribution of this study is the discussion and suggestion of three possible concepts that represent a better implementation of DMAIC and DMADV as a breakthrough to performance development. The researcher hopes this work would motivate scholars to conduct more studies on LSS DMADV and DMAIC practices and possible integration between then to enhance organization performance.

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