

Northumbria Research Link

Citation: Antony, Jiju, Swarnakar, Vikas, Salentijn, Willem, Shokri, Alireza, Doulatbadi, Mehran, Bhat, Shreeranga, McDermott, Olivia, Jayaraman, Raja and Sony, Michael (2023) A global study on applicability of ISO 18404:2015 for SMEs: an exploratory qualitative study. TQM Journal, 35 (7). pp. 1917-1934. ISSN 1754-2731

Published by: Emerald

URL: <https://doi.org/10.1108/TQM-08-2022-0276> <<https://doi.org/10.1108/TQM-08-2022-0276>>

This version was downloaded from Northumbria Research Link:
<https://nrl.northumbria.ac.uk/id/eprint/50202/>

Northumbria University has developed Northumbria Research Link (NRL) to enable users to access the University's research output. Copyright © and moral rights for items on NRL are retained by the individual author(s) and/or other copyright owners. Single copies of full items can be reproduced, displayed or performed, and given to third parties in any format or medium for personal research or study, educational, or not-for-profit purposes without prior permission or charge, provided the authors, title and full bibliographic details are given, as well as a hyperlink and/or URL to the original metadata page. The content must not be changed in any way. Full items must not be sold commercially in any format or medium without formal permission of the copyright holder. The full policy is available online: <http://nrl.northumbria.ac.uk/policies.html>

This document may differ from the final, published version of the research and has been made available online in accordance with publisher policies. To read and/or cite from the published version of the research, please visit the publisher's website (a subscription may be required.)



**A global study on applicability of ISO 18404:2015 for SMEs:
An exploratory qualitative study**

Journal:	<i>The TQM Journal</i>
Manuscript ID	TQM-08-2022-0276
Manuscript Type:	Research Paper
Keywords:	Standards, Lean, Six Sigma, Lean Six Sigma, Qualitative methods

SCHOLARONE™
Manuscripts

A global study on applicability of ISO 18404:2015 for SMEs: An exploratory qualitative study

Abstract

Purpose – ISO18404:2015 standard defines the proficiencies to the attainment of distinct competency levels with either Lean Manufacturing or Six Sigma or separately combined strategy Lean Six Sigma (LSS). The purpose of this paper is to perform a detailed investigation of the applicability of current Lean Six Sigma (LSS) competency standard in SMEs and examine the need for further improvement.

Design/Methodology/Approach – A qualitative-based semi-structured interview method was utilized globally by interviewing a group of LSS professionals with knowledge about the LSS implementation working in different leading organizations. All participants were asked to review the standard before the interview process to ensure that they are familiar with the standard.

Findings – The results reveal that the current ISO 18404:2015 standard does not fit SMEs to implement the LSS approach as it has several shortfalls that need to be fixed before its adoption or an urgent need to develop a more customised LSS standard for SMEs. The outcome further helps organizations understand theoretical knowledge about ISO18404:2015, its role in operational excellence implementation, pros, cons, critical success factors and required changes for further improvement within the standard.

Research limitations/implications –There were very limited baseline studies in the literature. A mixed method strategy that includes qualitative and quantitative data would yield better data so that more robust outcomes can be derived from the research.

Originality/value – To the best of authors' knowledge, this is the first empirical research on the applicability of ISO 18404:2015 for SMEs, which encapsulate opinions of LSS professionals working in several SMEs.

Keywords – ISO 18404:2015, Lean Six Sigma, Critical Success Factors, Industry 4.0, Quality 4.0, Continuous improvement.

Paper Type – Research paper

1. Introduction

With the awareness and demand for quality products and services, organizations implement a variety of quality improvement programs. The integration of these programs with a quality

1
2
3 management system (QMS) gives a better opportunity to achieve quality products and enhance
4 sustainability. The implementation of continuous improvement initiatives such as Total quality
5 management (TQM), Lean Manufacturing, Six Sigma, or Lean Six Sigma can be successful
6 when an organization follows the structured adoption process (Garza-Reyes, J. A. 2015).
7 However, various quality management standards provide structured guidelines to implement
8 continuous improvement initiatives as well as train people to achieve implementation success
9 (Antony et al. 2021a). According to the statement of Marques et al., (2013) and Sa et al., (2020),
10 a systematic collaboration of operational excellence program with QMS act as a critical success
11 factor (CSF) for the successful deployment of continuous improvement initiatives within the
12 organization. There are various QMS standards published by the ISO, for instance, ISO 9000
13 family (stands for all types of organization), IATF 16949 (stands specific for the automotive
14 sector), ISO 13485 (stands for medical devices), ISO 22000 (for food), ISO 20000 (for
15 services), ISO 27001 (for IT), AS 9100D (for Aerospace) and many more (www.plex.com;
16 www.iso.org).

17
18
19
20
21
22
23
24
25
26
27
28 In late 2015, ISO published a standard for Operational Excellence (such as Lean or Six
29 Sigma or LSS) known as ISO 18404:2015. This new standard defines the competencies for the
30 attainment of specific levels (Six Sigma Black belts, Green Belts, Master Black Belts) in order
31 to implement Lean Manufacturing, Six Sigma, or LSS in the organization. The primary
32 objective of this standard is to provide certification to both individuals and organizations in
33 Lean Manufacturing and Six Sigma implementation program. The certification provided by
34 this standard is only for three levels (i.e., Green Belts, Black Belts, and Master Black Belts).
35 They have not included White Belts or Yellow Belts in their standard which are getting popular
36 over the past few years in many organisations. As per the rule of ISO, each standard needs to
37 be reviewed at regular intervals of time for either revision purpose or its confirmation, or
38 withdrawal purpose. Based on the rule, ISO 18404:2015 was reviewed by the ISO in 2021 and
39 the results stated the confirmation of the standard (International Standards Organisation, 2021).
40
41
42
43
44
45
46
47

48
49
50
51
52
53
54
55
56
57
58
59
60
Based on the norms of ISO, the standard should capture all the requirements needed to
provide structured training to individuals and implement OPEX initiative in the organization
successfully (Antony et al. 2021a). Thus, the lack of required information, guidelines, or
facilities in the standard result in the implementation failure of any initiatives (Antony et al.
2021). There is limited research study observed related to ISO 18404:2015. Few authors have
referenced this standard in their research work (Ward and Caklais, 2019; Herrera and van
Hillegersberg, 2019a, b). Further, many practitioners and LSS professionals have commented
on the pros, cons, and requirements of ISO 18404:2015 standard. The principal author of ISO

1
2
3 18404:2015 stated that the involvement of decision-makers and LSS professionals was
4 minimum during the development of this standard (Bendell 2016).

5
6 Recently, a team of OPEX researchers from different parts of the world have further
7 investigated the use of the standard which resulted in the following two publications: (i) “A
8 study into the Pros and cons of ISO 18404: Perspectives from Leading practitioners” (Antony
9 et al, 2021a) and (ii) “Global study into the pros and cons of ISO 18404: a convergent mixed
10 method study and recommendations for further research” (Antony et al, 2021b). These two
11 studies specifically focused on ISO 18404:2015 standard and concluded that the views of LSS
12 professionals on the standard were pretty much inconsistent. For instance, most of the
13 interviewed practitioners were queried about the fitness of purpose of this standard and its
14 suitability. Whilst some other practitioners asked about the universal benefits of the standard
15 during the implementation of Operational Excellence (OPEX) initiatives.

16
17 The main purpose of the present research is to understand the research background executed
18 for improving this standard and its applicability for LSS implementation in SMEs. Based on
19 this purpose in mind, the following research questions were developed:

- 20
21
22
23
24
25
26
27
28
29
30
31 (1) *Is there a need for an ISO standard on LSS for SMEs?*
32 (2) *What are the pros and cons of ISO 18404 in the context of SMEs?*
33 (3) *What are the CSFs of implementing ISO 18404 in SMEs?*
34 (4) *Which requirements in the standard are less/ not applicable for SMEs?*
35 (5) *Is there a need to include Yellow Belt level in the existing standard?*
36 (6) *What should be the future skills to be possessed by LSS professionals which are not*
37 *explicitly covered in the standard?*
38
39
40
41
42
43

44
45 The layout of the article is as follows: Section 2 presents a detailed review of literature on ISO
46 18404, section 3 discusses research methodology adopted for the present study. The results of
47 the study have been reported in Section 4. This is followed by discussion and implications in
48 Section 5. Section 6 presents the conclusion, limitations and direction for future research.

51 52 53 **2. Literature review**

54
55 The ISO 18404 standard was introduced by Prof. Tony Bendell and published by the ISO in
56 the year of 2015 (Bendell, 2016; allaboutlean.com/iso-18404). This standard was developed to
57 explain the competencies at the organisational level to implement quality improvement
58 methods such as Lean Manufacturing, Six Sigma, or LSS. Previously, the other standard was
59
60

1
2
3 published by ISO TC69 for applying related statistical approaches. The two standard named
4 ISO 13053-1 “Quantitative methods in process improvement - Six Sigma DMAIC
5 methodology – Part 1” and ISO 13053-2 “Quantitative methods in process improvement – Six
6 Sigma Tools and techniques – Part 2” were published by the ISO in the year of 2011. Most
7 researchers understand that ISO 18404:2015 is the upgraded version of the ISO 13053 series
8 (Antony et al. 2021a). In reality, there are very few similarities between these standards, and
9 the authors of the standard have mostly ignored most of the critical contents described in the
10 ISO 18404:2015, explicitly discussed in the ISO 13053 series (Chiarini, 2013;
11 LeanCompetency.org, 2016).

12
13
14
15
16
17
18
19 In the ISO 18404:2015 standard, the competency is primarily set for the Lean
20 practitioners (Six Sigma Green belt), Lean leaders (Black Belt), and experts (Master black
21 belt). In this standard, they have excluded White belts and Yellow Belts. These levels combine
22 the equivalent competencies and follow the Six Sigma belt structure. The standard has
23 described the performance criteria, competencies list, standard training, etc., for each
24 competency level (Roser, 2016; Morgan, 2017). Many researchers and organizations
25 understand that ISO 9000 standard series is a backbone for the development of Total Quality
26 Management (TQM) initiatives in many organisations (Douglas et al., 2003). Still, the lack of
27 the right curriculum for the LSS initiative and specific standardization for the LSS adoption is
28 an important issue for most organizations (Antony, 2004; Laureani and Antony, 2012).
29 However, the standard can be adopted in organizations for various reasons such as fulfilling
30 customer requirements, attaining regulatory requirements, increasing market share and profit,
31 improving the product and process quality, reducing defects, etc. (Witcher, 1994; Roser, 2016).
32 Adopting a standard and being a certified organization needs too much paperwork and high
33 cost, especially in the context of Small and Medium Sized Enterprises (SMEs). Further, during
34 the audit, an organization can face many challenges in effectively interpreting the standard with
35 the auditor (McTeer and Dale, 1996).

36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 **2.1. Introductory reception of ISO 18404:2015**

51 The ISO 18404 standard concept was first delineated at the European Educator Conference
52 held at Buckingham, the UK in 2015. This standard was developed in connection with two
53 different groups: the Royal Statistical Society (RSS) and British Standards Institute (BSI).
54 Many researchers, practitioners, professionals, and industry personnel who participated in the
55 conference commented that the current standard lacks the adoption process, techniques,
56 competencies, and standardization related to the LSS initiatives (Bendell, 2016). There is a
57
58
59
60

1
2
3 lack of consultation and involvement of LSS practitioners, government bodies, and
4 professionals in developing the standard (Morgan, 2017). However, several authors (Kikuchi
5 and Suzuki 2018; Kazakova, 2021) commented that the publication of any standard does not
6 mean it would work effectively for the purpose it was developed. Similarly, the study
7 performed by Antony et al., (2021a) stated that the organization has low uptake of ISO 18404
8 standard adoption. This statement has been also verified through Google search and there are
9 only two examples related to ISO 18404 certified organizations were found. Other studies have
10 also discussed these examples (Ward and Caklais, 2019; Lopez, 2021). There was no
11 refinement observed in the ISO 18404:2015 standard over the period since its development in
12 2015. Further, no researchers have discussed the benefits, challenges and motivation of ISO
13 18404:2015 implementation in organizations through case studies or empirical studies like ISO
14 9001.
15
16
17
18
19
20
21
22
23
24

25
26 In 2015, when ISO 18404 standard was published, the ISO committee members of the USA
27 and Japan voted against implementing this standard (Ishiyama, 2016). American Society for
28 Quality (ASQ) is a well-known and possibly one of the most reputed quality professional
29 bodies in the world. This society provides training for Six Sigma adoption and conducts a high-
30 level exam to provide different credentials based on the body of knowledge and experience of
31 participants. ASQ categorizes its certification in different competency levels such as Six Sigma
32 White Belts, Yellow Belts, Green Belts, Black Belts, and Master Black Belts (asq.org/quality-
33 resources/six-sigma/belts-executives-champions).
34
35
36
37
38
39
40

41 **2.2. Pros and Cons of ISO 18404:2015 standard**

42
43 ISO 18404:2015 standard was designed to guide organizational managers to adopt a
44 standardized program in their organizations (Rich and Malik, 2019; Herrera and van
45 Hillegersberg, 2019b). This standard helps organizations demonstrate the evidence that
46 training has followed the standard and enabled the options for competency assessment. The
47 standard also helps to hire the right competent individual (Morgan, 2017). Further, the standard
48 helps to provide training to Lean and Six Sigma professionals and allows the organization to
49 deploy continuous improvement initiatives. Moreover, it aids in providing certification at
50 different belt levels (Herrera and van Hillegersberg 2019a). One of the problems noticed with
51 the ISO 18404 creation it was developed by limited key players (Ishiyama, 2016; Morgan,
52 2017; Antony et al., 2021a). It can be noted that the ISO18404 standard provides certification
53 either for Lean or Six Sigma or both Lean and Six Sigma but does not certify Lean Six Sigma
54
55
56
57
58
59
60

1
2
3 (LSS) organizations (allaboutlean.com/iso-18404). It is also noteworthy that this standard
4 excluded the yellow belt which is adopted by many SMEs to manage work on the shop floor
5 (Pakdil et al., 2020). Many researchers and blog writers also observed the above-mentioned
6 problems in the ISO 18404 standard and argued that the current ISO 18404:2015 standard lacks
7 LSS competencies (allaboutlean.com/iso-18404; Antony et al. 2021a; b; servicesltd.co.uk).
8 However, there is a need for an LSS standard as the level of training provided to different belts
9 is not up to the mark, is not internationally recognized, and certification is given to very little
10 work (Bendell, 2016; servicesltd.co.uk).
11
12
13
14
15
16
17
18

19 When George (2002) first introduced the merger of Lean Manufacturing and Six Sigma as LSS,
20 it became one norm and was known in the industries. LSS plays a crucial role in organizations
21 changing their culture and works as a catalyst to enhance the continuous improvement of
22 culture (Prasanna & Vinodh, 2013). Roser (2016) highlighted that the adoption of ISO
23 18404:2015 standard in the organization is like getting a certification and then recertification
24 in the form of paper, but the implemented LSS program does not influence the organization's
25 culture. Moreover, Antony et al. 2021a, stated that most of the quality standards, including the
26 ISO 9000 series, have fundamental issues in that it creates a sense of complacency, and the
27 adopting organization or concerned personnel misunderstand that they have achieved 100%
28 quality after the adoption of these standards.
29
30
31
32
33
34
35
36
37

38 Most organizations have started Six Sigma Yellow Belts on the shop floor to increase the
39 awareness of this powerful problem solving methodology at its basic level and the integration
40 of tools in each phase of the methodology (Antony et al. 2021a). For this reason, organizations
41 provide training to those employees and get certification from competent societies like ASQ,
42 ISO, IASSC, etc. One of the difficulties found in the current version of ISO 18404:2015 is that
43 it has not included Yellow Belts in this standard (Pakdil et al., 2020). Further, the Design for
44 Six Sigma (DFSS) or Design for LSS (DFLSS) are equally or more important to be talked
45 about or discussed in the current version of ISO 18404:2015 (Watson and DeYong, 2010).
46 However, all the above discussions are explicitly explained in the ASQ body of knowledge as
47 competencies of LSS practitioners (Watson and DeYong, 2010). Similarly, implementing ISO
48 18404:2015 standard is expensive, and it is difficult to bear the high cost for SMEs in both
49 developing and developed countries (Ishiyama, 2016; Kazakova, 2021). The standard does not
50 help to provide proper guidelines to professionals and practitioners for LSS implementation in
51 SMEs (Kazakova, 2021). Furthermore, many researchers have stated that the current ISO
52
53
54
55
56
57
58
59
60

1
2
3 18404:2015 standard has two major issues: (i) *the standard is too prescriptive, and (ii) it goes*
4 *against a holistic approach* (Watson and DeYong, 2010; Ishiyama, 2016; Kazakova, 2021).
5
6 The prime objective of this research is to explore subjectively how this standard can be
7
8 modified to be implemented LSS in SMEs.
9

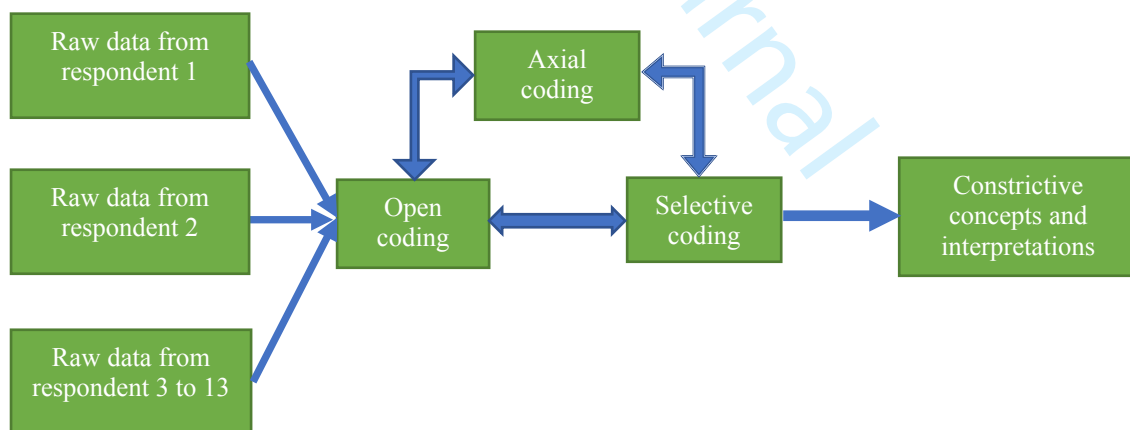
10 11 12 **3. Methodology**

13 The methodology applied in the present study includes a qualitative data collection strategy
14 through semi-structured interviews using a purposive sampling approach (Charmaz and
15 Belgrave, 2007). Senior managers and consultants with significant knowledge and experience
16 in ISO 18404, Lean manufacturing, Six Sigma, and Lean Six Sigma working in SMEs (e.g.
17 more than 10 years experience) were selected for this study. Therefore, the
18 information/opinion/view gathered from these ground-level people will be more meaningful
19 and useful (Antony et al. 2021a). According to Organisation for Economic Co-operation and
20 Development (OCED, 2005), This approach helps researchers judge and select people,
21 organizations, experts, etc., and study their characteristics under the predefined sample
22 (Tonjang and Thawesaengkulthai, 2020; Antony et al. 2021a).
23
24
25
26
27
28
29
30
31

32 The present study adopted an exploratory qualitative design to capture the thoughts of
33 top/senior managers and consultants in-depth practical knowledge of ISO 18404 standard for
34 SMEs. The interviewees involved in this study were from countries such as Netherlands,
35 Canada, India, Belgium, Ireland, and United Kingdom. The prime objective was to choose
36 participants from various organizations and countries to include divergent viewpoints
37 regarding ISO 18404 standards for SMEs. A total of 14 participants were chosen for this study
38 (table 1), and their backgrounds and profile were obtained from the trusted social network
39 “LinkedIn”, a popular social networking site for professionals (Unkelos-Shpigel et al., 2015).
40 The selected sample size is enough as the data was saturated, and no new themes were emerging
41 (Guest et al., 2006; Saunders et al., 2018). A personalized invite was sent to each participant
42 through LinkedIn, the study participants who agreed were sent study objectives with a set of
43 interview questions related to the standard and its suitability for SMEs, ISO 18404 standard
44 and MS Teams/Zoom link. The developed questions were validated by 7 experts before
45 initiating the interview and improved their consistency based on the experts’ feedback. The
46 experts were chosen from both industry and academia who are familiar with ISO 18404
47 standard. The experts chosen from the industry were consultants who have been delivering
48 training and coaching managers in SMEs on Lean and Six Sigma projects. The interview
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 started at the scheduled time with a few demographic questions followed by 10 open-ended
4 questions. The questions asked to the participants were focused on ISO 18404 standard and
5 their relevance to SMEs and centered around our research questions outlined in the introduction
6 section.
7
8
9

10
11
12 Grounded Theory (GT) has been known as a flexible tool to carry out qualitative research into
13 theory development (Charmaz 2005). Instead of deductively obtained techniques, it is a theory
14 that is consecutively obtained through “social research” and is grounded in data (Goulding
15 1998). GT has emerged as a widely adopted approach across the social sciences field, as it
16 provides researchers the flexibility to develop, test, and strengthen new theories from their
17 research data (Achora and Matua 2016; Hussein et al., 2020). Therefore, the present study used
18 the ground theory approach for the qualitative data analysis. The recorded information gathered
19 by the respondents was added to the Atlas Ti9 software for analysis purposes (Friese, 2019;
20 atlasti.com). For open coding, three different techniques were applied that resulted in a list of
21 themes within the data. Further, axial coding is used to categorize themes, and selective coding
22 is applied to condense data into specific categories (Charmaz and Belgrave, 2007; Cascio et
23 al., 2019). The data analysis process is summarized in Figure 1. As mentioned earlier, 10
24 questions were asked about the applicability of the ISO 18404 standard applicable to SMEs to
25 the interview participants.
26
27
28
29
30
31
32
33
34
35
36
37



38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Figure 1. Data analysis process

Table 1. Participants details

Participants name	Role/Title	Years of experience	Company Type	Company size	Geographical location
P1	LSSBB	>25	Automotive	SME	Netherland
P2	LSSBB	>20	Oil industry	SME	Netherland
P3	LSSBB	>15	Consultancy	SME	Netherland
P4	LSSBB	>15	Consultancy	SME	Netherland
P5	LSSBB	>20	Industrial Production	SME	Canada
P6	LSSBB	>20	Petrochemical industry	SME	Saudi Arabia
P7	LSSBB	>25	Nuclear Energy	SME	Saudi Arabia
P8	LSSBB	>15	Windmill manufacturer	SME	India
P9	LSSBB	>15	Consultancy	SME	India
P10	LSSBB	>25	Medicine manufacturer	SME	Ireland
P11	LSSMBB	>20	Consultancy	SME	Ireland
P12	LSSBB	>20	Consultancy	SME	Belgium
P13	LSSMBB	>25	Industrial Production	SME	UK
P14	LSSMBB	>15	Cosmetics	SME	UK

4. Results

Figure 2 is a word cloud that depicts the critical themes from the interview. This cloud highlights the keywords frequently used by the authors and participants in the present work. The word's size, place, and centrality in the cloud represent the relative prominence of respective themes (Munoz Lopez, 2010). Word cloud is an effective approach for visually communicating the frequent words in the text document (Lohmann et al., 2015). As the prime objective of the present study is to understand the participants' perceptions, the word cloud is the most prominent approach for visually representing and analyzing the most important and frequently used keywords. The most frequently used keywords were ISO 18404, standard, SME, critical success factors, pros and cons, future skills, Lean Manufacturing, Six Sigma, and Lean Six Sigma. For a quick understanding of readers, the detailed analysis plan is provided in the form of a diagram in Figure 3.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

“We will adopt very likely in the future since the company already has adopted several ISO standards (9001, 14001) because my organization is just getting started LSS implementation”. (P1)

“Yes, we adopted the standard for training to green and black belts”. (P2)

“No, my company did not adopt this standard. It also doesn't have a commercial way of expanding the standard”. (P4)

“No, we follow whatever clauses in other generic standards such as ISO 9001:2015”. (P5)

“No, as our company follow the integrated management systems which integrate all the standard needed by the company for training such as ISO 9001-1400, 18001 and other IT standard” (P6)

“We did not adopt the standard yet for training in our organization but we can adopt it in the future if needed”. (P11)

“No, as we have developed a standardized definition of problems typology as well as developed a separate setup/roadmap and toolkit for Lean practitioners, Six Sigma yellow belt, green belt, and master black belt”. (P12)

4.2. Pros and Cons of current ISO 18404 standard for SMEs

To answer the research question, **“What do you think are the pros and cons of a standard on LSS being applicable for SMEs?”**. The feedback received from the respondents are:

“Pros include: having a certain level of maturity in a standard and cons are: anybody can issue ISO 18404 standard with very few set of skills”. (P3)

“The cons include: the current standard is complex and not included the complete material required for LSS implementation success, and the pros are it gives a knowledge about LSS deployment”. (P4)

“The major pros include: it could add more structure and definitions to the LSS, helps organizations with the task of training, helps organizations when they hire talented individuals as well as whenever they deploy LSS to their suppliers and vendors. Similarly, the major cons include lack of management dedication, resources, functions, departments, hierarchal layers to fully comply with this standard, compliance to other existing standards, and unnecessary/extra cost required for responsibilities to administer to develop/review/maintain the whole set of new documentation related to LSS projects”. (P5)

“The advantages are: the standard provides the guidelines in a systematic way. The consequence is that the standard is not up to date as nowadays many new tools/techniques are introduced which are not included in the current standard”. (P6)

“The main pros are: competencies and performance indicators that captured in the current standard may help industries to understand how to adopt this standard in organizations and the cons are: the suggested competencies and indicators did not create for outcome purpose”. (P9)

“The pros include: it provides definitions of LSS, provide the guidelines for the training, and help organizations to hire right people whereas cons are it is not structured and ready to adopt material, especially for SMEs”. (P10)

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

“Pros include: having a certain level of maturity in a standard and cons are: focus on individual competencies of different belts rather than organizations” (P13)

4.3. The major shortfalls in the current ISO 18404 standard for LSS implementation in SMEs

To answer the research question **“In your view, which requirements in the standard are less/ not applicable for LSS deployment in SMEs?”**. The respondents were provided their opinion on the same which are:

“The current standard is useful but too general so that SMEs will not find clear guidelines on how to implement LSS”. (P1)

“The competencies for Green belts and Black belts provided in the present ISO 18404 standard is not applicable for all organizations and the standard did not clearly explain each competency required to implement LSS in various organizational settings with varied sizes” (P2)

“The only shortfall I can see is about the way information is delivered. The sub-sections 6.6 in the existing ISO 18404 standard does not help to deploy the overall objective strategy of the organization and sub-section 6.7 opens the door for added complexity and cost by employing more burden on organizations to requalify every three years which is redundant and not needed if organizations already in compliance with other standards” (P5)

“I would not say it’s not applicable because its applicability varies based on industry, in some industries the standard is applicable and in some not, the standard is looking fine in my view but the systematic elaboration in the existing standard opens a new path for organizations to understand this standard clearly”. (P6)

“The standard has lack of business process reengineering concept, lack of leadership concepts, lack of social and human resources related factors”. (P9)

“The current standard more focus on the competencies of individuals rather than focus on competencies of different types of industries”. (P11)

“The SMEs do not generally need MBB or BB. If this level is required, they can be hired for the short term. The use of statistical software is less applicable because the use of Microsoft Excel is adequate. Moreover, the exact competencies of each belt may be interpreted as very rigid” (P14)

4.4. Critical success factors for the adoption of ISO 18404 standard for SMEs

To answer the research question **“What are the CSFs of implementing ISO 18404 in SMEs?”**. The respondents were provided their opinion on the same which are:

“One of the CSFs is a clear guideline for the adoption of ISO 18404 standard in SMEs”. (P1)

“The CSFs are: having top management commitment and involvement, and having leadership competencies” (P2)

1
2
3 “I think CSFs are: a big focus on the belts, management should know how to create a good
4 environment of various belts, good communication, availability of proper resources, etc.” (P3)
5

6
7 “The CSFs to implement ISO 18404 are: linkage of company objective to the functional level
8 objectives and having a strategic planning process in place”. (P7)
9

10
11 “I think the CSFs can be having collaboration with the local educational institute or
12 government agencies, consideration of Black belts and Master Black belts and having training
13 opportunities”. (P9)
14

15
16 “The CSFs to implement ISO 18404 are: have leadership and change management strategy,
17 executing some small-scale wins, have clear objective and vision, and have cultural change
18 mindset”. (P10)
19

20
21 “The CSFs to adopt ISO 18404 could be level of maturity for process thinking and availability
22 of enough belts” (P13)
23

24 **4.5. Applicability of ISO 18404 standard as standard on LSS for SMEs**

25 To answer the research question “**Do you think the current ISO 18404 standard is applicable**
26 **as a standard on LSS for SMEs?** If so, why? If not, why not?”. The respondents were provided
27 their opinion on the same which are:
28

29 “Not in its current form! In my opinion, there is no difference made in the size of companies,
30 companies themselves will adjust the standard to the size of their organization. This leads to
31 arbitrariness” (P1)
32

33 “Yes, the current standard is applicable as standard on LSS for SMEs because its referred
34 standard but it needs quite an elaboration”. (P3)
35

36
37 “I think the current standard is not applicable because it has too much focus on the individuals
38 and not even focused on the system or management of a company. The standard should focus
39 on the feeling factor to improve it”. (P4)
40

41
42 “No, I don’t think it is applicable because there is more complexity in the existing standard”
43 (P5)
44

45
46 “No, not in its present form, it needs a high-level structure to understand the difference
47 between various levels of organizations. SMEs are not financially reached so they cannot spend
48 too much to understand the specific role, functions, requirements, and implementation process
49 of LSS” (P7)
50

51
52 “No, the standard cannot help in the current form as the information delivered at the present
53 form in the standard is unstructured and SMEs do not have much time and experts to dig into
54 the content and digest it. Therefore, a clear explanation of the skills needed per phase and
55 steps of the DMAIC roadmap will be more beneficial” (P12)
56

57
58 “No, SMEs may not have the time/resource to fully demonstrate each competency and this
59 would suggest that they have failed. Maintaining competencies (section 5.4c) can be very
60 difficult due to resources. The same applies to section 6.7”. (P14)

4.6. Need for Lean/Six Sigma/Lean Six Sigma standard for SMEs

To answer the research question **“Do you think there is a need for a Lean or Six Sigma or LSS standard for SMEs in the ISO 18404 standard? If so, why? If not, why not?”**. The respondents were provided their opinion on the same which are:

“No there is no need for any LSS standard, especially for SMEs, there is only need to clearly describe the adoption difference between large and SMEs in current ISO 18404 standard” (P1)

“I think it would be good because if there is a specific standard you know how to judge the level of maturity in the LSS towards organization”. (P3)

“I do not see any need or value to create an ISO standard for LSS, especially for SMEs as most other ISO standards (ISO 9001:2015; IATF 16949:2016; ISO 13485:2016, etc.) have clauses for continuous improvement initiatives which are enough and having a specific standard for Lean or Six Sigma or LSS which adds more complexity and cost to companies which result in many organizations will choose not to be part of it”. (P5)

“Yes, there is a need for specific LSS standard because different organizations use a different strategy, tools, and techniques for LSS implementation which result in some organization failing to implement LSS. If there is a specific standard for LSS then everyone can follow the same and achieve the benefits”. (P6)

“I don’t think there is a need to develop a specific standard for LSS because if we develop a new standard, there will be no opportunity to improve the existing one”. (P9)

“Yes, there is a need to create an ISO standard for LSS because it will guarantee a common understanding, application, and interchangeability on the field”. (P12)

“Yes, there is a need to create an ISO standard for LSS because it gives a guideline to implement LSS in SMEs which could change the mindset of companies to adopt it (P13).

“Yes, there is a need for an LSS standard for SMEs because SMEs have limited resources when compared to bigger organizations. Creating a generic standard for all organizations will not take into account the issues that SMEs are faced with”. (P14)

4.7. Use of ISO 18404 standard for LSS implementation in SMEs

To answer the research question **“How do you think the standard could support the implementation of LSS in SMEs?”**. The respondents were provided their opinion on the same which are:

“There is a need to create a clear guideline on how companies should implement LSS and create a matrix which describes the functions, tasks, and responsibilities of team members and employees”. (P1)

“It could be providing a structured roadmap to implement LSS so that it could give a lot of guidelines/contents about setting up LSS in organizations”. (P3)

1
2
3 “The ISO 18404:2015 standard may help as a reference document for organization managers
4 to discuss what training programs should be developed for different competency levels”. (P6)
5

6
7 “The standard should focus on the leadership development, motivation factors, human
8 resource factors, and social factors”. (P7)
9

10
11 “There is a need to define program outcomes, provide a good set of data for exercise, include
12 project and exercise-based learning programs”. (P9)
13

14
15 “There is a list of competencies, which may use for training. The current standard may help
16 as a discussion document for management teams to discuss what training programs should be
17 developed”. (P10)
18

19
20 “The standard could support the implementation of LSS within SMEs by demonstrating the
21 various options and competencies that are available to companies to make improvements
22 without being overly strict on the criteria that are suggested”. (P14)
23

24 **4.8. Need for curriculum for yellow belts in the current ISO 18404 standard**

25 To answer the research question “**As the ISO 18404 standard covers the curriculum for both**
26 **Green belts and Black belts, is there a need within the standard to cover the competency of**
27 **Yellow Belts, especially for SMEs**”. The respondents were provided their opinion on the same
28 which are:
29

30
31 “Yes, of course. I would also describe the White belt so that all LSS belts understand the
32 training requirements of the various belts”. (P1)
33

34
35 “I don’t think there is a need for coverage for yellow belts as these belts have learned basics
36 and have not gone to further details about how to make the changes in the organizations”. (P2)
37

38
39 “Yes, the curriculum for the yellow belt needs to be included because SMEs have fewer
40 financial resources to bring BBs or MBBs” (P7)
41

42
43 “No, as yellow belts have fewer skills or knowledge. The duration of learning for yellow belts
44 is too short and this huge syllabus cannot be captured in a short time duration”. (P8)
45

46
47 “For adoption of LSS a thorough knowledge about LSS tools and techniques required that
48 Yellow belts can unable to capture”. (P9)
49

50
51 “Yes, the curriculum for the yellow belt needs to be included. The standard should also include
52 a curriculum for White belts (WB) so that training can be fine-tuned to several levels. Project
53 leaders will start addressing “simple” problems with a basic YB and tackle more sophisticated
54 problems with GB, BB, and MBB”. (P12)
55

56
57 “Black belts are not needed in SMEs; they can be hired for a short time if necessary. Also, the
58 cost of having a black belt full-time could be expensive for SMEs. Yellow belts should be
59 covered in the standard as they are more relevant to the project types that are experienced in
60 SMEs. Lean issues are easier to resolve and relevant to SMEs in general when compared to
statistical variation”. (P14)

4.9. Future skills to be acquired by the LSS professionals

To answer the research question “*what should be the future skills to be posed by LSS professionals which are not explicitly stated or covered in the standard?*”. The respondents were provided their opinion on the same which are:

“*I think more understanding and knowledge required related to different types of problems (organization wise), develop the connection between machine, vision, and strategy, and a sort of understanding on how to connects these*”. (P3)

“*I think the competencies of professionals are quite complete, therefore professionals should have excellent knowledge about competencies required to implement LSS as well as having a good knowledge about new/existing tools and techniques applicable for its implementation*”. (P4)

“*To have the skills and knowledge required to get into Industry 4.0 and Quality 4.0 to deal with the next wave of technology related to machine learning, internet of things, artificial intelligence, etc.*”. (P5)

“*The standard did not talk much about the statistical tools and techniques, it is only telling refer another standard, and the standard was introduced in 2015. However, with the advent of Industry 4.0 and Quality 4.0, the standard should include specific skills related to Blockchain, Robotic Process Automation, Big Data, IoT, AI, and Simulation to name but a few here*”. (P6)

“*The future skills related to management system approach and system thinking need to be acquired*”. (P7)

“*LSS professionals should learn how to integrate the LSS with Industry 4.0 and how to capture the relevant data as well as making decisions on the data*”. (P9)

“*The future skills related to industry 4.0, big data, process mining, new/existing tools and excellent knowledge to give better/faster answers to the questions asked in the DMAIC steps*”. (P12)

“*The future skills related to existing and new LSS tools and techniques, emerging technologies, and concept of design thinking must have in LSS professionals*”. (P13)

4.10. Further changes required in the ISO 18404 standard

To answer the research question “*What would you change in the standard if you could, and why or why not?*”. The respondents were provided their opinion on the same which are:

“*The three changes suggested are: need to create a matrix which describes the functions, tasks, and responsibilities of team members and employees for SMEs and include White belt and Yellow belt in the current standard*”. (P1)

“*LSS implementation is only succeeded if there is proper/continuous communication strategy followed but this does not only apply for GBs and BBs. Management and all employees must get in touch with each other and follow the same strategy*”. (P2)

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

“I would connect Project management level for Black belts and Program management to the level of Master Black belts and the difference is that project management is about to deliver results and program management is about moving towards the organisational goals”. (P3)

“Need to develop a clear guideline and structured steps to implement LSS in SMEs. In addition, the cultural aspects should be captured better in the revision of the standard”. (P4)

“A change is definitely needed in the existing standard. The standard should provide more detailed information about what the things can be considered for the specific types of industry such as for construction, production, laboratory, maintenance, service provider, etc. which guide the people working in SMEs”. (P6)

“The changes include: role of top management need to be incorporated, an elaborate bit more from an application point of view with core study, and competencies of yellow belts need to be included”. (P7)

“Need to include existing and new tools and technologies, the process of design thinking and set the benchmark for the standard”. (P11)

5. Discussion and implications

The results show that the applicability of the current ISO 18404:2015 standard for LSS implementation in SMEs is very low, as very few respondents have recommended this standard for implementation in its current form. At the same time, the idea of a specific standard for LSS implementation was welcomed positively by most respondents. Thus, there is an urgent need to develop a standard specific to SMEs or make some additional amendments to the existing standard so that SMEs can utilize it. The results of the study found that only a single interviewee is currently using the standard to train their Green and Black Belts. The interviewee's opinions on the cons of the ISO 18404 standard for LSS implementation in SMEs were broad, but their views on the pros were limited. Further, the opinion of contributors regarding the inclusion of the curriculum for the yellow belts in the current standard was mismatched. Most interviewees suggested the inclusion of a curriculum for the LSS yellow belts in the standard, but few of them opposed it. However, nearly all professionals listed shortfalls, CSFs, future skills to be posed by LSS professionals, and some amendments to improve the standard.

Based on the view of the majority of the contributors, the current standard does not provide clear guidelines and a structured roadmap to implement the LSS in SMEs. Further, the competencies described for Green and Black belts do not apply to all types of organizations. Moreover, the standard lacks consideration of the business process reengineering concept, leadership concepts, and social and human resources-related factors. It is absolutely essential to understand that a recent study has shown that nearly 50% of skills for successful Black Belts should be related to soft skills (Antony and Karaminas, 2016). The interviewees listed a few CSFs that could help adopt the ISO 18404 standard in the organization. Most participants suggested CSFs were “a clear guideline for the adoption of ISO 18404 standard in SMEs, top management commitment and involvement, leadership competencies, availability of required resources for implementation, good working environment for LSS belts, linkage of company objectives to the functional level objectives, collaboration with the local institute or

1
2
3 government agencies, training and education facilities and facility to demonstrate projects
4 profitability to the bottom lines”.

5
6 The results also demonstrated how the current ISO 18404 standard could help managers
7 implement LSS in SMEs. In this perspective, participants of the study suggested that the need
8 arises to create clear guidelines which guide organizational managers to implement LSS in
9 SMEs and develop a matrix that defines the functions, tasks, competencies, and team’s
10 responsibility. Further, the need arises to define program outcomes, provide a good data set for
11 exercise, and include project and exercise-based learning programs in the standard. Moreover,
12 a curriculum for Yellow belts could be included, which will help SMEs financially due to
13 limited budget and resources. They further suggested the list of skills to be acquired by the LSS
14 professionals to implement LSS in SMEs successfully and improve the bottom line results. The
15 participants suggested that LSS professionals should have a better understanding related to
16 effective communication strategy, competencies required for LSS implementation, use of
17 new/existing tools and techniques, knowledge of management system approach and system
18 thinking, good command of Industry 4.0, Quality 4.0 technologies, and hands-on experience
19 with emerging tools such as machine learning, internet of things, artificial intelligence, big
20 data, process mining to deal with the next wave of technology. The existing standard has failed
21 to capture the future skills of LSS professionals with the advent of Industry 4.0. The authors
22 would argue that future LSS professionals should be competent with AI, Big Data, IIoT, and
23 Simulation to name but a few here. The integration of LSS with the above emerging
24 technologies will make LSS professionals more competitive in the future.

25
26 Regarding the further amendments in the standard, the contributors suggested developing a
27 structured framework and providing systematic guidelines to implement LSS in SMEs. The
28 framework should be developed by collaborating LSS professionals, practitioners, decision-
29 makers, academicians, and government agencies. Based on their comments, the standard
30 should include a program matrix. This matrix describes the functions, tasks, and
31 responsibilities of team members and employees for SMEs and consists of a curriculum for the
32 yellow belts. Further, the suggestion was that the standard should be clearly written and
33 properly discussed the detailed information about what needs to be done to implement LSS in
34 SMEs. It should also cover the LSS implementation strategy for specific types of industry such
35 as construction, production, laboratory, maintenance, service provider, etc. These gaps will
36 open a new opportunity to improve the quality of the standard and make it more inclusive.

37
38 Organizations can refer to the outcome of the present study to understand the concept and use
39 of ISO 18404:2015 standard in SMEs in terms of LSS implementation and its real applicability.
40 Further, they can understand the actual need for this standard, its advantages and disadvantages,
41 benefits, and the CSFs that help support the implementation of LSS in any organization.
42 Moreover, the study emphasized the future skills to be required for LSS professionals, and the
43 necessary improvements needed within the current ISO 18404:2015 standard. This study
44 suggests the importance and needs to either revise the current standard with keeping the
45 challenges of SMEs in mind or create a novel LSS standard for SMEs. Therefore, while
46 revising the current standard or creating a new standard, authors of the standard should involve
47 more professionals, practitioners, decision-makers, and even academicians to ensure the
48 readiness of the standard.

49
50 It is also suggested that authors review the standard a few times before publishing it to confirm
51 whether the created standard is fulfilling the requirement for which it has been created and can
52 achieve the targeted goal. The authors can also check the soundness of revised/newly created
53
54
55
56
57
58
59
60

1
2
3 standard with the help of 4-5 experts. Amongst these challenges, the high certification cost is
4 a major concern for SMEs. Therefore, authors should prepare the standard by considering a
5 proper budgetary plan so that organizations managers can easily understand about financial
6 requirements needed for the certification. A high certification cost is one of the critical issues
7 to refuse the implementation of such standard in SMEs. So one of the most important things
8 that must be cared for by authors during the development of the standard is that the certification
9 cost should be affordable for SMEs. While organization managers should consider the benefits
10 of the standard in terms of successful implementation of initiatives for which the standard is
11 applied, customer satisfaction, quality improvement, service improvement, and is
12 internationally recognized. In summary, the opinions of interviewees are overall mixed but the
13 majority of contributors thought that the current ISO 18404:2015 standard does not fit SMEs
14 to implement the LSS approach, the standard has several shortfalls that need to be fixed before
15 its use. Therefore, the authors recommend that the revision promised by ISO TC in 2021 of
16 this standard take place before the scheduled systematic review is held in 2026.
17
18
19

20 21 **6. Conclusion, limitations, and directions for future work**

22 The ISO 18404 standard is not widely known, adopted, heard, or read, as evidenced by the
23 limited studies related to its applicability and role for LSS deployment in SMEs. It is a better
24 opportunity to either update or rewrite the current standard or create the new one as the present
25 form of this standard is too difficult to understand and get knowledge from. It also does not fit
26 the purpose of LSS implementation in SMEs according to this research project because there
27 is a lack of structured framework and systematic guidelines that are important to implement
28 any OPEX initiatives. There is an urgent need to revise and rewrite the current standard, which
29 can be certified by the competent authority. The standard should include the yellow belts
30 curriculum, and provide more focus on human capital and resources as well as soft skills,
31 bringing management and others to the workplace and organizational culture. The standard can
32 also add a new skillset for different belts level and cover the concept of OPEX integration with
33 emerging technologies such as Industry 4.0 and Quality 4.0. This is a major weakness of the
34 existing ISO 18404 standard, especially with the advent of digital transformation in many
35 organisations today.
36
37
38

39 As there is a lack of real case examples showing the ISO 18404:2015 deployment in SMEs,
40 this gap can motivate researchers for further research studies such as case studies. The main
41 limitation of this research is that the strategy used to collect the data was qualitative and
42 therefore only subjective views of the participants were captured. Moreover, the number of
43 interviewees is comparatively limited. Therefore, we may not make a robust conclusion from
44 this study. The low sample size was because most organizations are not aware of the ISO
45 18404:2015 standard, and the organization that follows the standard is not measuring its
46 effectiveness. The findings imply that extensive research needs to be conducted with a large
47 (quantitative and qualitative) data set. The authors plan to carry out the study to understand the
48 effectiveness of ISO 18404:2015 standard-based training and do a comparative analysis with
49 other popular and recognized training programs. However, in order to carry out such research,
50 there are just handful of companies around the world that are familiar with and use the standard.
51 In the future, we are also aiming to measure the impact of the ISO 18404 standard on
52 organizational performance. This means the researchers would like to compare the impact of
53 companies using ISO 18404 against companies that are not utilizing the standard but using
54 certification programs of leading quality professional bodies such as ASQ.
55
56
57
58
59
60

References

A. Laureani, J. Antony, *Standards for Lean Six Sigma certification*. International Journal of Productivity and Performance Management, 61 (1), 110-120 (2012)

Achora, Susan, and Gerald Amandu Matua. 2016. Essential methodological considerations when using grounded theory. *Nurse Researcher* 23: 31–36.

Antony, J. (2004), “Some pros and cons of six sigma: an academic perspective”, *The TQM Magazine*, Vol. 16 No. 4, pp. 303-306.

Antony, J. and Karaminas (2016), Critical assessment on the Six Sigma Black Belt roles/responsibilities, skills and training: a global empirical study", *International Journal of Quality & Reliability Management*, Vol. 33 No. 5, pp. 558-573.

Antony, J., McDermott, O., Sony, M., Cudney, E.A., Snee, R.D. and Hoerl, R.W. (2021a), “A study into the pros and cons of ISO 18404: viewpoints from leading academics and practitioners”, *The TQM Journal*, Vol. 33 No. 8, pp. 1845-1866, doi: 10.1108/TQM-03-2021-0065.

Antony, J., McDermott, O., Sony, M., Powell, D., Snee, R. and Hoerl, R.W. (2021b), "Global study into the pros and cons of ISO 18404: a convergent mixed method study and recommendations for further research", *International Journal of Quality & Reliability Management*, Vol. ahead-of-print No. ahead-of-print. <https://doi.org/10.1108/IJQRM-10-2021-0356>

ATLAS.ti | The Qualitative Data Analysis & Research Software - ATLAS.ti (atlasti.com)

Bendell, T. (2016), “‘ServicesLtd’, it’s always good to question, but it’s always bad to ignore reality”, available at: <http://servicesltd.blogspot.com/> (accessed 5 October 2021).

Cascio, M.A., Lee, E., Vaudrin, N. and Freedman, D.A. (2019), “A team-based approach to open coding: considerations for creating intercoder consensus”, *Field Methods*, Vol. 31, pp. 116-130, doi: 10.1177/1525822X19838237.

Charmaz, K. and Belgrave, L.L. (2007), “Grounded theory”, in Ritzer, G. (Ed.), *The Blackwell Encyclopedia of Sociology*, Blackwell Publishing, Oxford, doi: 10.1002/9781405165518.wbeosg070.pub2.

Charmaz, Kathy. 2005. Grounded Theory in the 21st Century: Applications for Advancing Social Justice Studies. In *The Sage Handbook of Qualitative Research*, 3rd ed. Edited by Norman K. Denzin and Yvonna Sessions Lincoln. Thousand Oaks: Sage Publications Ltd., pp. 507–35.

Chiarini, A. (2013), “A comparison between companies’ implementation of Six Sigma and ISO 13053 requirements: a first investigation from Europe”, *International Journal of Process Management and Benchmarking*, available at: <https://www.inderscienceonline.com/doi/abs/10.1504/IJPMB.2013.057724> (accessed 15 February 2021).

1
2
3 Douglas, A., Coleman, S. and Oddy, R. (2003), “The case for ISO 9000”, The TQM Magazine,
4 Vol. 15 No. 5, pp. 316-324, doi: 10.1108/09544780310487712.

5
6 Friese, S. (2019). *Qualitative data analysis with ATLAS. ti*. Sage.

7
8 Garza-Reyes, J. A. (2015). Lean and green—a systematic review of the state of the art
9 literature. *Journal of Cleaner Production*, 102, 18-29.

10
11 George, M.L. (2002), *Lean Six Sigma: Combining Six Sigma Quality with Lean Production*
12 *Speed*, McGraw-Hill, NY.

13
14 Goulding, Christina. 1998. Grounded theory: The missing methodology on the interpretivist
15 agenda. *Qualitative Market Research* 1: 50–7.

16
17 Guest, G., Bunce, A. and Johnson, L. (2006), “How many interviews are enough? An
18 experiment with data saturation and variability”, *Field Methods*, Vol. 18, pp. 59-82.

19
20 Herrera, M. and van Hillegersberg, J. (2019a), “Using metamodeling to represent lean six
21 sigma for IT service improvement”, 2019 IEEE 21st Conference on Business Informatics
22 (CBI). 2019 IEEE 21st Conference on Business Informatics (CBI), pp. 241-248, doi:
23 10.1109/CBI.2019.00034.

24
25 Herrera, M. and van Hillegersberg, J. (2019b), “Using metamodeling to represent lean six
26 sigma for IT service improvement”, 2019 IEEE 21st Conference on Business Informatics
27 (CBI). 2019 IEEE 21st Conference on Business Informatics (CBI), pp. 241-248, doi:
28 10.1109/CBI.2019.00034.

29
30 <https://asq.org/quality-resources/six-sigma/belts-executives-champions>. Accessed date:
31 30/08/2022

32
33 <https://www.allaboutlean.com/iso-18404/> Accessed date: 30/08/2022

34
35 <https://www.iso.org/management-system-standards.html> Accessed date: 28/07/2022

36
37 [https://www.plex.com/products/quality-management-system/types-quality-management-](https://www.plex.com/products/quality-management-system/types-quality-management-systems)
38 [systems](https://www.plex.com/products/quality-management-system/types-quality-management-systems) Accessed date: 28/07/2022

39
40 Hussein, F., Stephens, J. and Tiwari, R. (2020), “Grounded theory as an approach for exploring
41 the effect of cultural memory on psychosocial well-being in historic urban landscapes”, *Social*
42 *Sciences*, Vol. 9, p. 219. doi: 10.3390/socsci9120219.

43
44 International Standards Organisation (2021), ISO 18404:2015, ISO, available at:
45 <https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/06/24/62405.html>
46 (accessed 7 September 2021).

47
48 Ishiyama, K. (2016), JSQC News, JSQC.org, available at:
49 <https://www.jsqc.org/q/news/events-list.html>.

50
51 Kazakova, E.V. (2021), Problems of Implementation of ISO 18404: 2015 at Enterprises in
52 Russia, available at: <https://www.elibrary.ru/item.asp?id541581971> (accessed 27 June 2020).

1
2
3 Kikuchi, T. and Suzuki, M. (2018), “Kaizen and standardization”, in Otsuka, K., Jin, K. and
4 Sonobe, T. (Eds), *Applying the Kaizen in Africa: A New Avenue for Industrial Development*,
5 Springer International Publishing, Cham, pp. 111-149, doi: 10.1007/978-3-319-91400-8_4.
6

7
8 LeanCompetency.org (2016), LCS Briefing: ISO 18404, Lean Competency System, available
9 at: <https://www.leancompetency.org/briefing-iso-184042015/> (accessed 13 October 2021).
10

11 Lohmann, S., Heimerl, F., Bopp, F., Burch, M. and Ertl, T. (2015), “Concentric cloud: word
12 cloud visualization for multiple text documents, in: 2015 19th international conference on
13 information visualisation”, Presented at the 2015 19th International Conference on Information
14 Visualisation, pp. 114-120, doi: 10.1109/iV.2015.30.
15

16 Lopez, J. (2021), Rotoplay - products made under lean manufacturing, ROTOPLAY, 7 April,
17 available at: <https://www.rotoplay.eu/2021/04/07/abc-rotomoldeo-the-first-spanish-rotomouldingcompany-certified-in-lean-manufacturing-according-to-iso-18404/> (accessed 13
18 October 2021)
19
20

21
22 Marques, P., et al. (2013), “Integrating six sigma with ISO 9001”, *International Journal of Lean*
23 *Six Sigma*, Vol. 4 No. 1, pp. 36-59
24

25 McTeer, M.M. and Dale, B.G. (1996), “The attitudes of small companies to the ISO 9000
26 series”, *Proceedings of the Institution of Mechanical Engineers. Journal of Engineering*
27 *Manufacturer*, Vol. 210 No. 5, pp. 397-403.
28

29 Morgan, R. (2017), “ISO 18404: should you adopt standardised Lean (and Six Sigma)
30 certification?”, *StAndrewsLean*.
31
32

33 Munoz Lopez, S. (2010), *Process Definition For The Implementation of an Energy Efficiency*
34 *Program in Manufacturing Focused on Key Performance Indicators*, [WWW Document],
35 Polite, available at: <https://www.politesi.polimi.it/handle/10589/783> (accessed 16 April 2021).
36

37 OECD, 2005, *Organisation for Economic Co-operation and Development SME and*
38 *Entrepreneurship Outlook: 2005*, OECD Paris, page 17.
39

40 Pakdil, F., Toktas,, P. and Can, G.F. (2020), “Six sigma project prioritization and selection: a
41 multicriteria decision making approach in healthcare industry”, *International Journal of Lean*
42 *Six Sigma*, Vol. 12 No. 3, pp. 553-578, doi: 10.1108/IJLSS-04-2020-0054.
43
44

45 Prasanna, M., & Vinodh, S. (2013). *Lean Six Sigma in SMEs: an exploration through literature*
46 *review. Journal of Engineering, Design and Technology*, 11(3), 224-250.
47

48 Rich, F. and Malik, T. (2019), *International Standards for Design and Manufacturing: Quality*
49 *Management and International Best Practice*, 1st ed., Kogan Page, London: New York.
50

51 Roser, C. (2016), “Lean Standard” ISO 18404 – A Questionable Idea ..., *AllAboutLean.com*,
52 11 October, available at: <https://www.allaboutlean.com/iso-18404/> (accessed 27 June 2020).
53
54

55 Sa, J.C., Vaz, S., Carvalho, O., Lima, V., Morgado, L., Doiro, M. and Santos, G. (2020), “ A
56 model of integration ISO 9001 with Lean six sigma and main benefits achieved”, *Total Quality*
57 *Management and Business Excellence*, Preprint, doi: 10.1080/14783363.2020.1829969.
58
59
60

1
2
3 Saunders, B., Sim, J., Kingstone, T., Baker, S., Waterfield, J., Bartlam, B., Burroughs, H. and
4 Jinks, C. (2018), "Saturation in qualitative research: exploring its conceptualisation and
5 operationalisation", *Qual Quant*, Vol. 52, pp. 1893-1907, doi: 10.1007/s11135-017-0574-8.

6
7 servicesltd.co.uk. It's Always Good to Question But It's bad to Ignore Reality
8 (servicesltd.co.uk) [https://www.servicesltd.co.uk/post/2018/04/23/its-always-good-to-](https://www.servicesltd.co.uk/post/2018/04/23/its-always-good-to-question-but-its-bad-to-ignore-reality)
9 [question-but-its-bad-to-ignore-reality](https://www.servicesltd.co.uk/post/2018/04/23/its-always-good-to-question-but-its-bad-to-ignore-reality) Accessed Date: 30/08/2022
10
11

12 Tonjang, S. and Thawesaengskulthai, N. (2020), "A systematic literature review of TQM and
13 innovation in healthcare - ProQuest, in: a systematic literature review of TQM and innovation
14 in healthcare", Presented at the ISPIM Conference Proceedings, Manchester.
15

16 Ulmer, J. (2011), A Study of Asq and Sme Members on the Effects of Continuous Improvement
17 Practices and Certifications on Quality Cost for Small-To-Midsized, available at: [https://www.](https://www.bookdepository.com/Study-Asq-Sme-Members-on-Effects-Continuous-Improvement-PracticesCertifications-on-Quality-Cost-for-Small-Midsized-United-St-Jeffrey-M-Ulmer/9781243484437)
18 [bookdepository.com/Study-Asq-Sme-Members-on-Effects-Continuous-Improvement-](https://www.bookdepository.com/Study-Asq-Sme-Members-on-Effects-Continuous-Improvement-PracticesCertifications-on-Quality-Cost-for-Small-Midsized-United-St-Jeffrey-M-Ulmer/9781243484437)
19 [PracticesCertifications-on-Quality-Cost-for-Small-Midsized-United-St-Jeffrey-M-](https://www.bookdepository.com/Study-Asq-Sme-Members-on-Effects-Continuous-Improvement-PracticesCertifications-on-Quality-Cost-for-Small-Midsized-United-St-Jeffrey-M-Ulmer/9781243484437)
20 [Ulmer/9781243484437](https://www.bookdepository.com/Study-Asq-Sme-Members-on-Effects-Continuous-Improvement-PracticesCertifications-on-Quality-Cost-for-Small-Midsized-United-St-Jeffrey-M-Ulmer/9781243484437) (accessed 13 October 2021).
21
22

23 Unkelos-Shpigel, N., Sherman, S. and Hadar, I. (2015), "Finding the missing link to industry:
24 LinkedIn professional groups as facilitators of empirical research", 2015 IEEE/ACM 3rd
25 International Workshop on Conducting Empirical Studies in Industry, Florence, pp. 43-46, doi:
26 10.1109/CESI.2015.14.
27
28

29 Ward, S.A. and Caklais, S. (2019), "Piloting the deployment of ISO 18404 in the construction
30 sector, an approach to organisational transformation", Proceedings 27th Annual Conference of
31 the International Group for Lean Construction (IGLC), available at:
32 [https://www.academia.edu/39749367/Piloting_the_Deployment_of_ISO18404_in_the_Const](https://www.academia.edu/39749367/Piloting_the_Deployment_of_ISO18404_in_the_Construction_Sector_An_Approach_to_Organizational_Transformation)
33 [ruction_Sector_An_Approach_to_Organizational_Transformation](https://www.academia.edu/39749367/Piloting_the_Deployment_of_ISO18404_in_the_Construction_Sector_An_Approach_to_Organizational_Transformation) (accessed 5 October 2021).
34
35

36 Watson, G.H. and DeYong, C.F. (2010), "Design for six sigma: caveat emptor", *International*
37 *Journal of Lean Six Sigma*, Vol. 1 No. 1, pp. 66-84, doi: 10.1108/20401461011033176.
38

39 Witcher, B. (1994), "The adoption of total quality management in Scotland", *The TQM*
40 *Magazine*, Vol. 6 No. 2, pp. 48-53, doi: 10.1108/09544789410054055.
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60