International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:11, No:4, 2017

Lean Models Classification: Towards a Holistic View

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Abstract**—**The purpose of this paper is to present a classification of Lean models which aims to capture all the concepts related to this approach and thus facilitate its implementation. This classification allows the identification of the most relevant models according to several dimensions. From this perspective, we present a review and an analysis of Lean models literature and we propose dimensions for the classification of the current proposals while respecting among others the axes of the Lean approach, the maturity of the models as well as their application domains. This classification allowed us to conclude that researchers essentially consider the Lean approach as a toolbox also they design their models to solve problems related to a specific environment. Since Lean approach is no longer intended only for the automotive sector where it was invented, but to all fields (IT, Hospital, ...), we consider that this approach requires a generic model that is capable of being implemented in all areas.

Keywords**—**Lean approach, lean models, classification, dimensions, holistic view.

I. INTRODUCTION

THE lean approach, which was created in Japanese workshops, aims to eliminate waste while improving quality. This approach has been subject to several changes. Hines [1] considers its evolution as being focused on quality in the early 1990s, on quality, cost and delivery in the late 1990s, on the value system from 2000s. Lean achieves these objectives using different principles and methods [2]. This approach is of interest to process managers in several areas. However, these managers encounter several barriers during its implementation. De Souza [3] classified these barriers in the industrial and hospital sectors, and concluded that there are obstacles that are either independent of the sector or directly related to it. Among the raised problems, are those related to the Lean terminology, which is domain independent. These types of problems have been pointed out by other authors such as [4], [5], who mentioned the lack of understanding of the Lean approach as the main problem. Mostafa [6] also stated that the failure in the process of implementing the Lean approach is often due to insufficient understanding of the Lean concept itself. For Demeter [7], this ambiguity around Lean comes from several sources: (a) Toyota's production system itself has been significantly improved over the last 40 years [8], [9]; (b) the fact that several companies consider themselves Lean, even though they are at very different stages of development; (c) the reality that researchers use various definitions for the Lean term, so there is no common terminology [1]. The introduction of another book by Womack [10] entitled "Lean thinking", describes Lean principles and opens new avenues for Leanness, and thus leads to a further lack of clarity.

We consider that it is important to understand the concepts of the Lean approach before proceeding with its implementation via a particular operating procedure.

The objective of this paper is to propose a classification for the models of the Lean approach in order to have a holistic view that would allow us subsequently to capture all the concepts related to this approach. The rest of the paper is organized as follow: the research methodology is presented in Section II, followed by a literature review of Lean approach models in Section III. In Section IV, we propose the dimensions used in Section V for the classification of these models. The results obtained from this classification are discussed in Section VI. Finally, we end up with drawing conclusions and perspectives.

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II. METHODOLOGY

Our objective is to provide a classification of Lean approach models according to several dimensions in order to have a holistic view of this approach. This vision will allow us to identify the most relevant concepts of the Lean approach. In order to achieve this objective, we will follow the methodology illustrated in Fig. 1. In this paper, we are particularly interested in the phases: Literature Review, Identification of dimensions and Classification of models.

The "Literature Review" phase consists of selecting and studying articles that focus on models of the Lean approach. These articles are divided into two categories as illustrated in Fig. 2. The first category focuses on the problems related to the application of Lean and focuses on the critical points that hinder the success of this approach. The second category focuses on developing Lean models with the aim of either proposing a Lean implementation method or measuring its effectiveness, i.e. evaluating the results obtained following the implementation of Lean approach, or proposing a method to diagnose process status.

In this paper, we focus on models that aim at facilitating the implementation of the Lean approach and then analyze the models and present the limitations of each one. This analysis will allow us, in the phase "Identification of dimensions", to retain the axes of classification of models.

The phase "Classification of the models" allows to generate several classes of models of the Lean approach and to identify those to retain for the capture of the concepts.

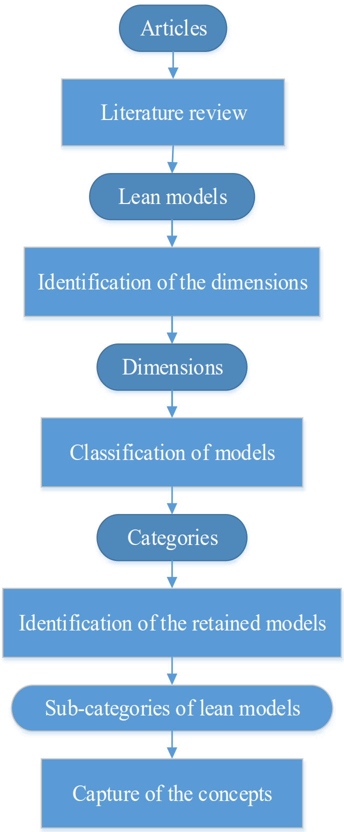

Fig. 1 Methodology

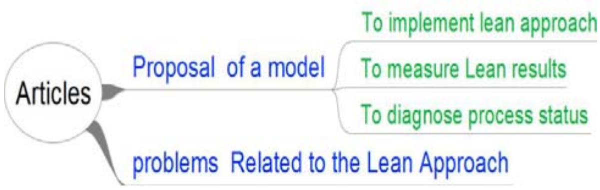

Fig. 2 Type of articles

III. Literature Review

As mentioned above, literature offers many models of the Lean approach. This variety of models can be due to its application in several fields such as industry, service, health, etc. We find it interesting to classify the articles according to the objective of the proposed model. On the one hand, we were interested in the models which were elaborated between 2000 and 2016, and which were published in English. In addition, the research did not limit our search to a particular domain. On the other hand, we tried to broaden our field of research in order to collect the maximum models possible so that the proposal presented in this paper would be more generic. From the selected articles, we noticed that the literature introduces several methods and techniques from other disciplines in order to improve the Lean approach. As an example, the authors adopted "fuzzy logic" [11]-[14], analytic hierarchy process [15]-[17], the Petri nets [18], balanced score [19], etc. In addition, the majority is concerned with measuring the results obtained via the Lean approach and its implementation, as illustrated in Table I.

TABLE I
CLASSIFICATION OF ARTICLES

		Number of articles
Lean Models	To implement lean approach	14
	To measure Lean results	27
	To diagnose process status	6
	Problems Related to the Lean approach	5

We are particularly interested in models that aim at facilitating the implementation of the Lean approach.

Fig. 3 illustrates the Toyota Production System model known as TPS House. This model does not respect the criterion of the time that we put to frame this paper, nevertheless we retained it because it is considered the first model of the Lean approach. It presents a set of tools and techniques in the form of a house that can mention the durability of the results obtained from the implementation of Lean. For Liker [2], the house is a structured system and it is strong only if the roof, pillars, and foundation are strong and where any weak link weakens the whole system. The basis of this house is stability, Heijunka, Standardize Work and Kaizen that serve to maintain and improve TPS and its pillars are Just-in-Time and Jidoka to finally reach the top of the house that represents the expected goals. According to TPS House, the purpose of Lean's implementation is to improve quality, reduce cost and lead-time.

TPS House is a model from the industrial sector and specifically from the automotive sector, which represents a solution to achieve the three objectives mentioned above through the application of tools and techniques.

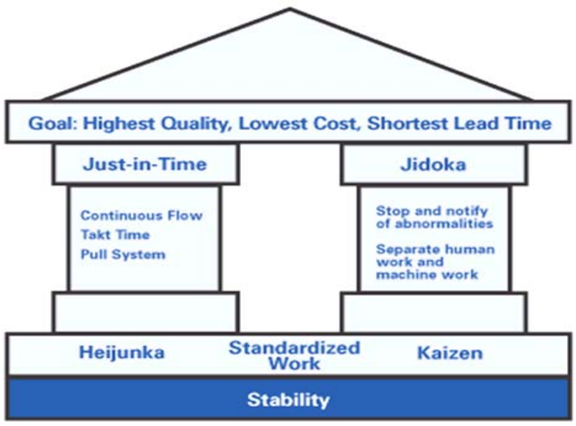

Fig. 3 Toyota Production System "House" [20]

This model is not flexible to environmental changes because it presents a series of tools without considering the human factor. In addition, this model presents a very limited number of tools due to its age. Hines [1] concluded that a distinction must be made between Lean thinking at the strategic level and Lean Production at the operational level. The goal here is to have a general view of Lean in order to

International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:11, No:4, 2017

apply the right tools and strategies to create added value to customers as shown in Fig. 4.

1) Strategic level: includes the five principles of Lean as Womack defined them. This level is independent of the working environment.
2) Operational level: focuses on the tools and approaches that can be applied at the workshop level. Unlike the first level, this one is highly dependent on the working environment.

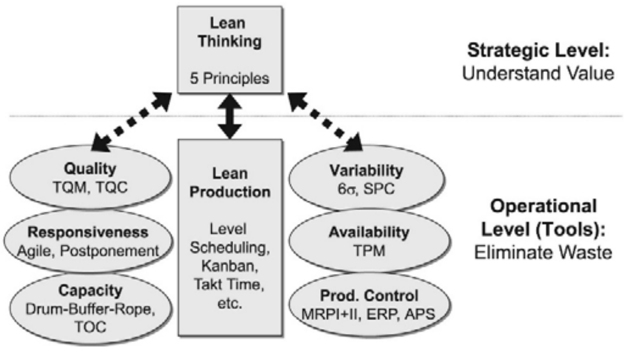

Fig. 4 Hines Model [1]

Hines [1] did not only cite Lean production-level tools at the operational level but has integrated approaches and even software at this level. They also pointed out that Lean reaches its limits when it is integrated outside repetitive high volume production. According to Hines [1], any tool or approach can be applied as long as it does not challenge the principles outlined at the strategic level.

The model of Hines [1] tried to reinforce the Lean approach by adding in its model approaches like Six Sigma and TQM, which are themselves complete approaches having a set of principles and tools that require a model for them to implement. This combination seems interesting but representing the whole in a single model is not a practical solution. In practice, this model is vague and presents only juxtaposed approaches. This model was adopted by [21], adapting it with the model suggested by [22]. Then, [21] stated that Lean can be characterized by four points of view as illustrated in Table II.

TABLE II
AN ILLUSTRATION OF THE FOUR DEFINABLE APPROACHES TO LEAN PRODUCTION [11]

	Discrete (Operational)	Continuous (Strategic)
Ostensive (Philosophical)	Leanness	Lean thinking
Performative (Practical)	Toolbox lean	Becoming lean

According to [23], Lean can be better explained by examining its objectives, principles and associated tools. The fundamental objectives for which we implement Lean are cost reduction, quality improvement and faster delivery through waste elimination and employee empowerment, as illustrated in Fig. 5.

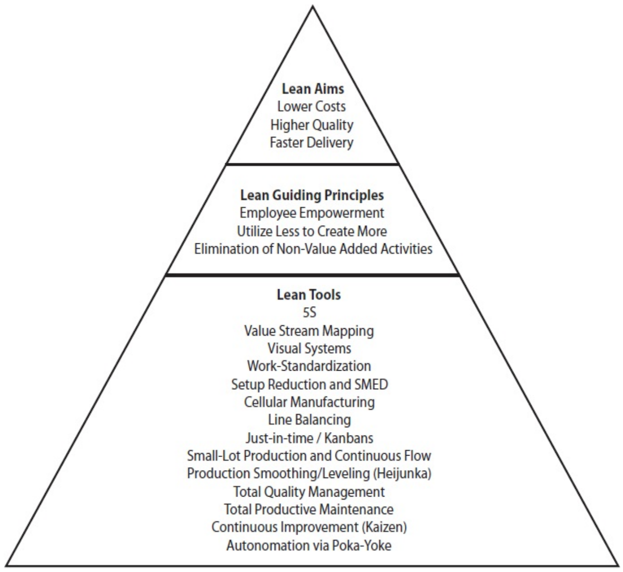

Fig. 5 Lean objectives, Guiding Principles, and Tools [23]

Abdulmalek [23] classified Lean's tools into two broad categories. Tools whose effectiveness depends strongly on the sector where they are applied as TPM and JIT and others are effective in all cases like VSM and 5S. In order to help managers to choose the most appropriate tools, he specified that the choice depends on two factors. The first concerns the characteristics of the products, namely: the variety and the volume of production. The second factor relates to the flow of material, which is characterized by the type of equipment and the product/flexibility ratio of the process.

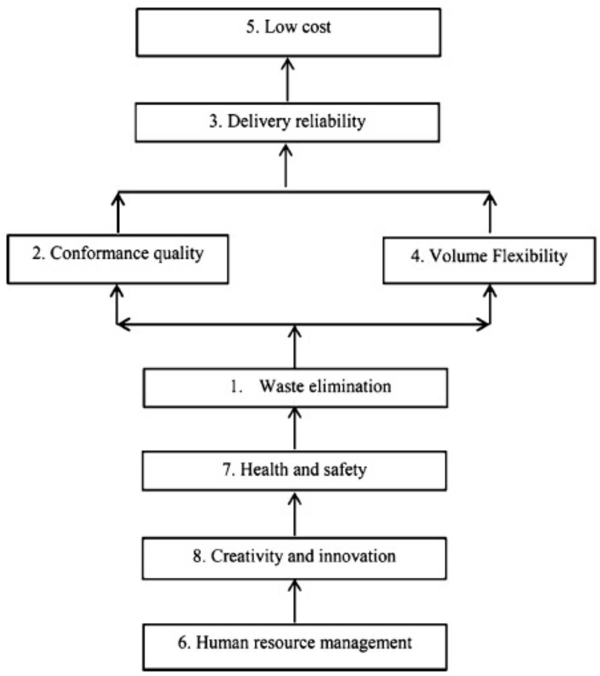

Fig. 6 ISM-based model for lean practice bundles [24]

The models of Abdulmalek [23] thus present tools according to the activity exerted by illustrating the cases where the Lean tools become difficult to use. These models focus only on the operational side without taking into account the strategic side. In its models, it is considered that there is no mutual influence between the product characteristics and the product flow. We believe that we cannot make a decision on the tools to be used based solely on the characteristics of the product or its flow.

The previously mentioned studies proposed their models without resorting to a method or an approach. References [24], [25] used the Interpretive structural modeling (ISM) approach, which is based on expert opinion to illustrate the interrelationships between Lean practices. Reference [24] grouped Lean's practices into packages based on the literature as well as expert opinions. He mentioned that the order of execution of these practice packets is very important to the successful implementation of Lean. In addition, he stressed that Lean practitioners must necessarily be able to understand the interrelations between these packages of practices. Meanwhile [24] has used eight packs of practices: Waste Elimination Practice Bundle, Compliance Quality Practice Bundle, Flexibility Practice Bundle, Low Cost Practice Bundle, Health and Safety Practice Bundle, Health and Safety Practice Bundle and Creativity & Innovation practice bundle. Fig. 6 illustrates the purpose of using the ISM approach.

Kumar [25] also used the ISM approach to define a sequence of execution of practice packets. He extracted 18 packages of practices from the literature and experts opinions as illustrated in Fig. 7.

We note that these two studies followed the same approach but obtained widely different results. This difference is justified by the analysis of literature and careers of the experts (academic or professional) as well as the domain. Indeed, by simply changing the expert, we can have a different result. We believe that we cannot generalize these two models. In other ways, we can say that these models are instances created to help solve a problem in an environment where parameters are well defined, and whenever a parameter changes we must reuse the ISM approach to have another model.

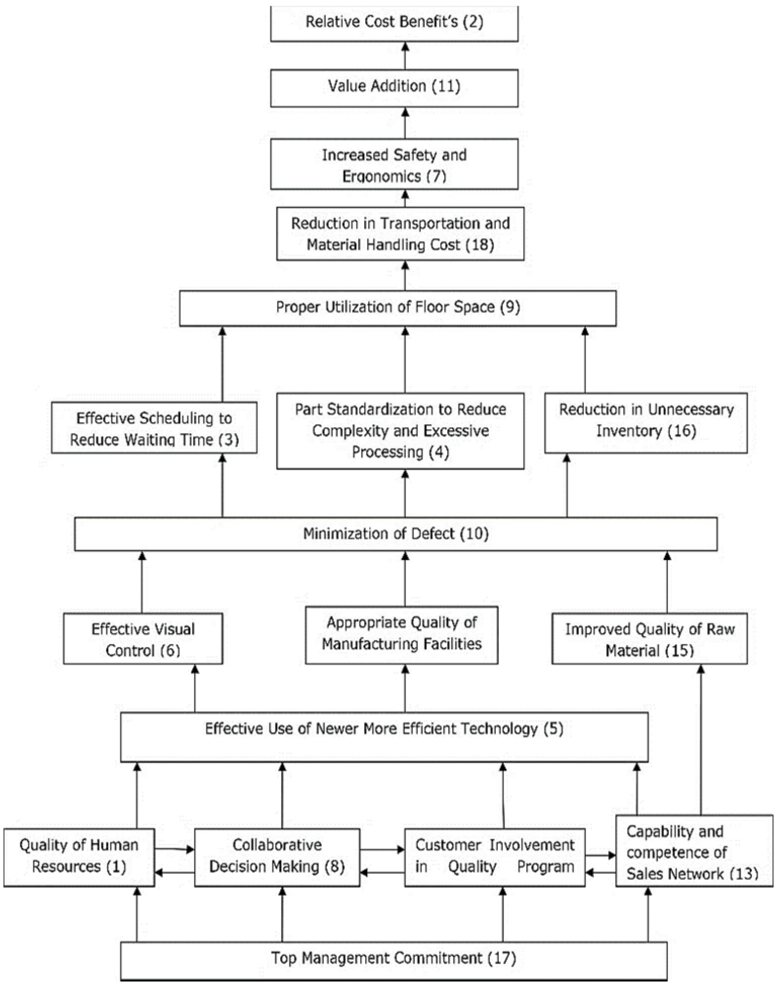

Fig. 7 ISM Based Model of Variables of Lean Manufacturing System Implementation [25]

We note here the existence of models of the Lean approach developed by companies. For example, Capgemini [26] stated that in order to successfully integrate Lean, it must incorporate three related principles: "Behavior Change", "Lean must be tackled holistically", and "Deployment must be progressive". Given that Capgemini is a company specializing in the service sector, it pointed out that 80% of Lean's profit comes from the change in staff behavior. To do so, it is necessary to approach the process, staff and organization as illustrated in Fig. 8. This approach must be deployed gradually level by level, following a coherent roadmap. Capgemini [26] represented a roadmap (Fig. 9) as a pyramid to emphasize the priority of activities. The latter consists of two levels in order to arrive at "BeLean".

1) Take control: a quick gain to create momentum and build a solid foundation on which we can improve. "Quick wins to create momentum and build a foundation of basic capability from which to progress"
2) Create Excellence: By bringing transformational results, integrating Lean culture into the new business.

Fig. 8 Behavioral change requires a holistic approach [26]

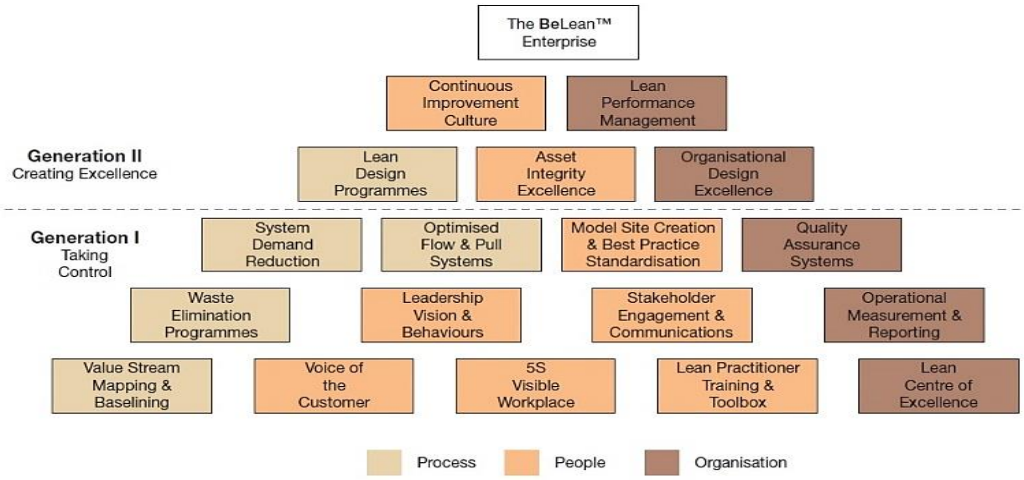

Fig. 9 Two levels of BeLean™ deployment [26]

Fig. 10 Renault Production System model [27], [28]

Capgimini has taken into account in its model three important axes: processes, staff and organization. However, we consider that for actions of the same level, the execution orders are not interesting and we can start with any action as long as we are in the same level. In addition, in this model, we note that there is an absence of principles and objectives.

Renault-Nissan Company also proposed its model, known as the "Renault Production System Rocket" (Fig. 10). This model represents a set of interdependent tools and techniques and their positions with respect to prerequisites and priorities. One of the main features of the "RPS rocket" is that its tools and techniques are applied synergistically with a predetermined order [27].

The Shingo model, as illustrated in Fig. 11, stressed that it is not enough to master Lean's tools and techniques in order to achieve a more profound and sustainable Lean transformation. Yet, they regarded them as the foundation of Lean transformation. This transformation requires understanding and integration of the underlying principles. Shingo's house consists of four levels: "Cultural enablers", "Continuous

Process Improvement", "Enterprise Alignment" and "Result" [29]. These dimensions encompass five basic management systems: product/service development, customer relations, operations, supply and a variety of management or administrative support systems [29]. Shingo's model of operational excellence is supported by a transformation process based on cultural change. The transformation methodology is based on the relationship between tools, outcomes, system and principles (Fig. 12).

Shingo [29] emphasized Lean's principles and details them in his model. On the other hand, he neglected the other axes of Lean.

To conclude, we have identified in this section, 10 models that all have the same objective to facilitate the implementation of the Lean approach in organizations. Each of them has its own vision and presents different solutions in order to succeed in this implementation. Yet there are models that are only basically a combination of existing models. In addition, it was noticed that there is a considerable change between the model of TPS HOUSE [20], which is considered the first model that models the Lean approach, and the following models that introduced new concepts to this approach.

IV. Identification Des Dimensions

There are many models of the Lean approach in the literature and each model tries to propose a solution to solve one or more problems related to its implementation. To help process managers choose the right model, but also to identify the limitations of these models, we propose to put in place a classification that allows a holistic view of Lean models, as illustrated in Fig. 13. To do so, we propose to analyze Lean models in three dimensions. The first dimension concerns the Lean axes: principles, tools/techniques and objectives. Relying solely on this dimension to evaluate a model will not be wise. Indeed, it does not examine the way in which the models approach the Lean axes, but it focuses only on the orientations of the models. In this case, we proposed to add a second dimension to our study. It consists of studying the models based on their fields of application. We proposed the following classification: a model is generic if it does not depend on a particular environment; a model is specific if it is dedicated to a particular domain (domain-specific) like the industrial domain for example; or to a particular sector (sector-specific) such as the automobile sector for example; or to a particular problem (specific-problem). These two dimensions allow us to focus on the Lean approach and the environment in which we can apply it. However, we consider that these dimensions are not yet sufficient for the model to be reliable. For this reason, we proposed adding the third dimension, which consists of evaluating the maturity of the models on the basis of the number of citations and the date of publication. On this dimension, we consider that there is a correlation between the importance of a model and the number of times it has been cited by other studies. This last dimension does not apply to models that have been developed by companies.

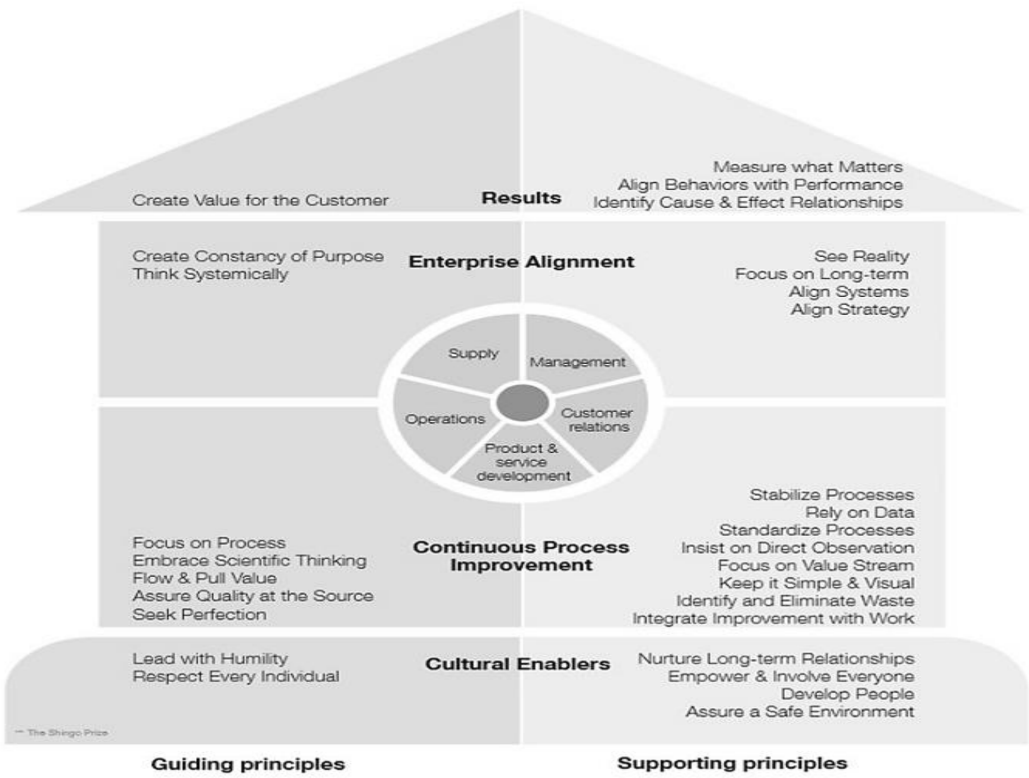

Fig. 11 Shingo principles of operational excellence [29]

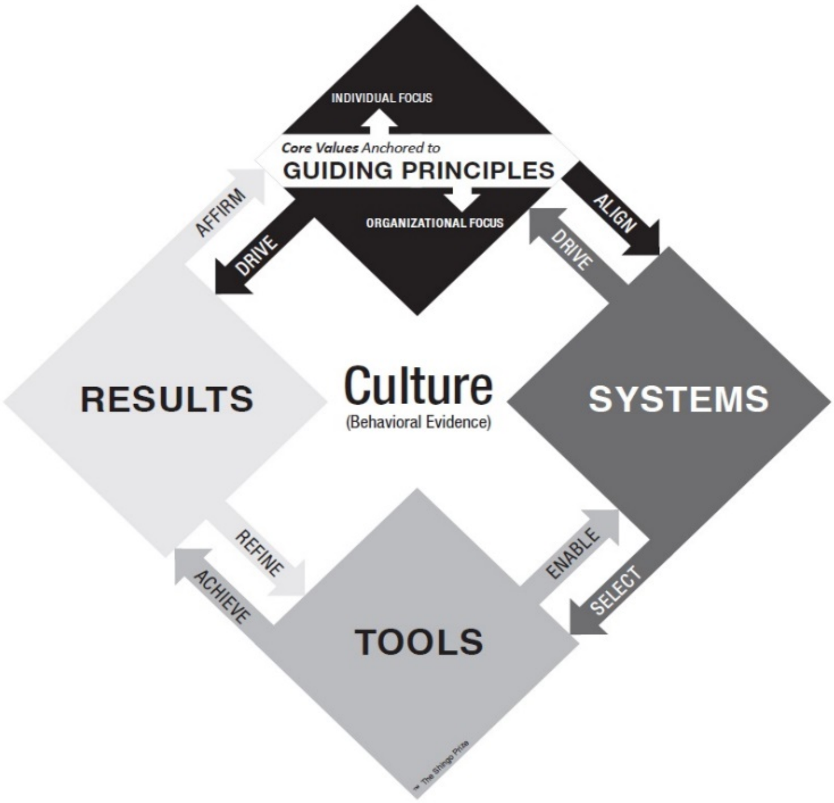

Fig. 12 Shingo Transformational Process [29]

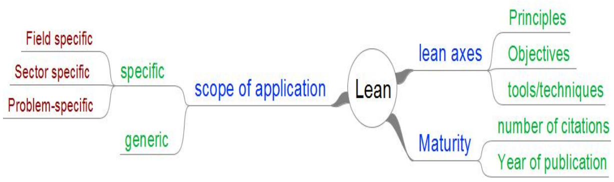

Fig. 13 Lean dimensions

TABLE III
CLASSIFICATION ACCORDING TO LEAN AXES

	Principles	Tools/ techniques	Objectives
[20]	*	*	*
[1]	*	*	
[28]		*	*
[26]		*	
[22]	*	*	
[21]	*	*	
[29]	*	*	
[25]		*	
[24]	*	*	
[23]		*	

TABLE IV
ELEMENTS OF EACH AXIS

	Principles	Tools / techniques	Objectives
[20]		JIT, Jidoka, Heijunka, …	Highest Quality, lowest cost, Shortest lead time
[1]	5 principals of [30]	Kanban, Takt Time, Six Sigma, TPM, …	
[28]		5S, Kaizen, Poka yoka, TPM, …	Daily excellence
[26]	Continuous Improvement Culture , Optimized Flow & Pull systems, …	5S, VSM	
[22]	Null	Null	
[21]	Null	Null	
[29]	Create value for customer, Focus on process, Respect every individual, …	Null	
[25]		Null	
[24]	5 principals of [30]	Null	
[23]		JIT, VSM, 5S, Kaizen, TPM, …	

V. CLASSIFICATION OF MODELS

After identifying the dimensions, we describe in this section our classification of models. Table III illustrates that all models incorporate tools and techniques contrarily to objectives and principles. The classification based on Lean's main axes helps us to understand the ideas of the authors.

According to them, Lean is a set of tools juxtaposed and if we master these tools, we can get good results. We note here that we do not share this idea with these authors. In addition, Table III shows only the axes mentioned in the Lean models. However, we have noticed that some models mention a Lean axis without mentioning the elements of this axis. As an example, the model developed by [29] highlighted the use of Lean tools but it did not include in its model the tools to use, and for this reason we indicated it by "Null" as illustrated in Table IV.Table V illustrates that there is a complete absence of generic models that we can use in any domain. In addition, despite the fact that Lean has become popular outside the industrial field, the majority of Lean models remain adapted to this field.

Table VI shows the number of citations and the year of publication of each article proposing the model. We note that the oldest articles have the most number of citations. However, this is not always true because if we compare the article of Abdulmalek [23] with that of Jadhav [24] or Kumar [25], we notice that even if the first is more recent than the other two, it has the most number of citations.

TABLE V
CLASSIFICATION ACCORDING TO FIELD OF APPLICATION

	Generic	Specific		
		Domain	Sector	Problem
[20]			Automobile	
[1]		Industry		
[28]		Industry		
[26]		Service		
[22]		Industry		
[21]		Industry		
[29]		Industry		
[25]				Automobile « India»
[24]				Automobile « India»
[23]		Industry		

TABLE VI
CLASSIFICATION ACCORDING TO MODEL MATURITY

Articles	Number of citations	Year
[20]	-	Null
[1]	1192	2004
[28]	-	2004
[26]	-	2005
[22]	1179	2007
[21]	386	2009
[29]	-	2012
[25]	9	2014
[24]	25	2013
[23]	107	2015

VI. Discussion

In order to have a holistic view on Lean models, this study proposed to analyze them in several dimensions. Fig. 14 shows that the majority of the work is interested in developing a model integrating tools and applicable in a specific field. Indeed, the authors tend to develop models to solve specific problems and not a generic model that encompasses the entire Lean approach with which we can generate instances for specific problems.

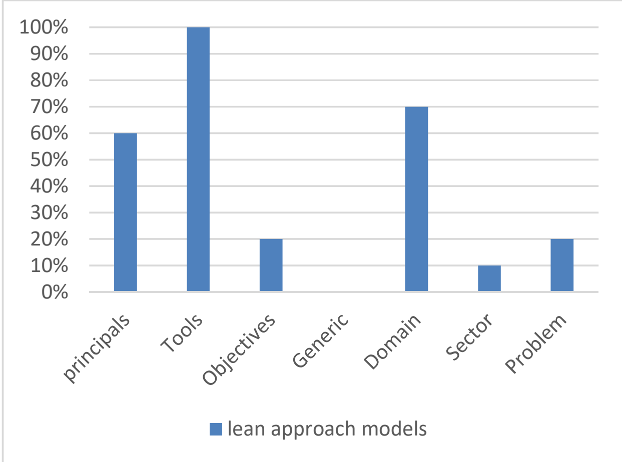

Fig. 14 Authors' directions

We also consider that focusing only on the tools makes it possible to understand how to apply Lean, but it does not answer the question: why will it be necessary to apply Lean? We believe this is the issue responsible for Lean's sustainability. Thus, we notice in Fig. 15 that models which are dedicated to a specific domain are more important than those that are dedicated to a specific problem. Therefore, we can conclude that models that apply to a larger field are more likely to be used more than models developed for a specific problem.

VII. Conclusion

In this paper, we have proposed a classification of models of the Lean approach according to several aspects, namely principles, tools / techniques and objectives that we considered as Lean axes; generic and specific to the domain, sector and problem that we have grouped in field of application,; The number of citations and the year of publication that we have grouped in maturity. We propose three main dimensions to better evaluate and compare models of the Lean approach proposed in literature. These models are intended to facilitate the implementation of Lean approach. We believe that this classification will allow the process manager to choose the right model before putting it in place and thus avoid a financial and personal commitment that will be doomed to failure. In this paper, this classification has illustrated that the majority of authors consider the Lean approach as a toolbox and we find that despite its popularity in several domains, there is still no Lean model that is capable of being implemented in all fields. Finally, we conclude that the models do not deal with the Lean axes in the same way and we reach to the same conclusion as [27] who pointed out that there is no common definition and classification of the principles and techniques of Lean. In this regard, we intend to remove this ambiguity on the Lean approach by identifying its concepts on which it is based in order to give a general framework of this approach based on the models retained in this paper.

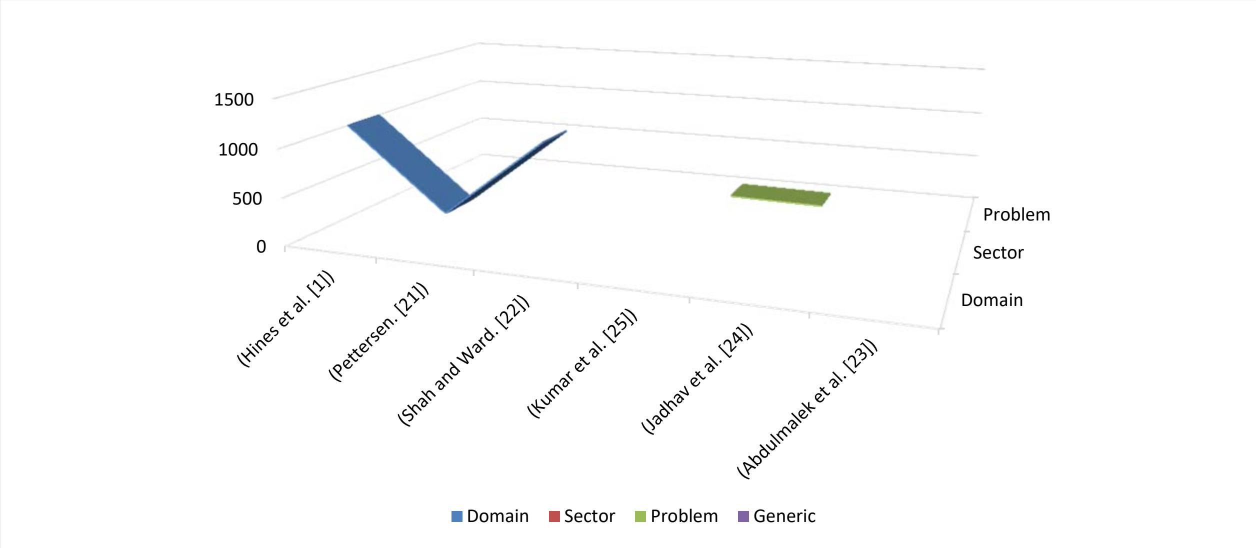

Fig. 15 Relationship between the number of citations and the scope

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