Sustainable Manufacturing: The Lean and Green Business Model

Andrea Brasco Pampanelli, Pauline Found and Andréa Moura Bernardes

Abstract Over the past few years there has been an emergent trend towards integrating a lean and green approach with a number of papers and books written, but most of these take an outside-in approach describing case studies from industry. This paper differs in that it takes an inside-out approach; describing a Lean and Green Business Model (L&GBM) developed within a major global engineering company. It describes the five key principles of a Lean and Green Business Model, (i) a stable value stream, (ii) identification of environmental impacts, (iii) measurement the environmental value streams, (iv) improvement of the environmental value streams and (v) continuous improvement. It further explains how the model applies a Kaizen approach for improving mass and energy flows of manufacturing environment that already possesses a basic deployment level in applying lean. Some of the key findings identified by the researchers highlight that (i) L&GBM has a different purpose than traditional Lean or Environmental Thinking, (ii) L&GBM covers the three dimensions of sustainability, (iii) L&GBM has a Lean to Green approach and (iv) L&GBM is an alternative approach to integrate environmental concerns into operations management which enhances workplace engagement in reducing the environmental impact of the manufacturing processes by leveraging the lean attributes of involvement and empowerment to the environmental functions within the organization that traditionally have focused on compliance.

A.B. Pampanelli
GKN Driveline Americas, Rua Joaquim Silveira 557,
91060-320 Porto Alegre, Brazil
e-mail: andrea.pampanelli@gkndriveline.com

P. Found (✉)
Buckingham Business School, University of Buckingham,
Buckingham MK18 1EG, UK
e-mail: pauline.found@buckingham.ac.uk

A.M. Bernardes
UFRGS, PPGEM Doctoral Programme, Av. Bento Gonçalves,
9500, Setor 4, Campus do Vale, 91501-970 Porto Alegre, Brazil
e-mail: amb@ufrgs.br

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1 Introduction and Purpose

Sustainability has become a legacy for the 21st century. It embodies the promise of societal evolution towards a more equitable and richer world in which the natural environment is preserved for generations to come. The quest for economic growth and social equity has become a major goal for most of the past 150 years. By adding concern for the carrying capacity of natural systems, sustainability ties together the current main challenges facing humanity.

Although the issues embodying sustainability are more than a century old, the concept of sustainable development itself was first described in the late 80s, following The Brundtland Report, a report by the World Commission on Environment and Development (WCED 1987) that describes the growing global awareness of the enormous environmental problems facing the planet, and proposes a shift towards global environmental action. The concern about sustainability encouraged society to support the development of a significant number of corporate practices, many applied to manufacturing business, such as Industrial Ecology, Industrial Symbiosis, Pollution Prevention, Cleaner Production, etc. with the ultimate goal of the supporting the sustainability dimensions of (1) profit, (2) people and (3) planet or the triple bottom line (Elkington 1997). Although all these studies and practices have contributed to create a new world paradigm, very few were able to contribute fully to all dimensions of sustainability (Lozano 2012). The term 'Green' is used in this paper and for the model proposed here to cover all concerns for the environmental impact of manufacturing and, in particular, to address the planet dimension of sustainability.

…manufacturing is the constant game of doing more with less… therefore manufacturing managers are constantly looking for new approaches to increase efficiency (Hopp and Spearman 2008). With the purpose of promoting a continuous improvement culture within the business, the expenditure of resources for any goal, other than the creation of value for the end customer, is considered to be wasteful. Lean thinking is one of these strategies that are explored by manufacturing to increase performance, contributing to the profit dimension, by developing and respecting people. The logic of lean thinking, with the emphasis on eliminating the seven classic wastes (Ohno 1988) can be redesigned and integrated to include an environmental, or green, dimension of sustainability, addressing all three dimensions of profit, planet and people.

…a gram of prevention is better than a kilogram of cure… therefore using less energy, material, generating less waste is prevention, and so good for the environment (Baas 2007). Minimizing waste produced in manufacturing, reducing the energy use and using the materials and resources in a more efficient way can lead to financial cost savings and a reduction of environmental impacts. Therefore,

integrating both concepts, lean thinking and sustainability, offers the foundation for a new business logic, where the pillars of sustainability, social, economic and environmental, can be understood by manufacturing and therefore supports business goals, requirements and needs.

The main objective of this paper is to propose a Lean and Green Business Model (L&GBM) where the environmental aspect of sustainability is added to the pure lean thinking concept in order to create a way of thinking that contributes to, and balances, the three sustainability dimensions of people, profit and planet (Elkington 1997). This model takes the Kaizen (continuous improvement) approach for improving mass and energy flows in a manufacturing environment that already possesses a deployment level in applying lean. Figure 1 presents the main role of the study.

This paper is based on action research developed from 2009 to 2013 by a team of lean and environmental experts from Brazil and UK. As an overall objective, it aims to propose a new and integrated way of thinking that:

- Integrates the pure 'Lean Thinking' concepts with an environmental, or 'Green Thinking' dimension;
- Contributes to, and balances, the three sustainability dimensions, or triple bottom-line of people (social sustainability) profit (economic sustainability) and planet (environmental sustainability);
- Uses the Kaizen approach for managing and improving environmental flows of mass and energy in manufacturing environment.

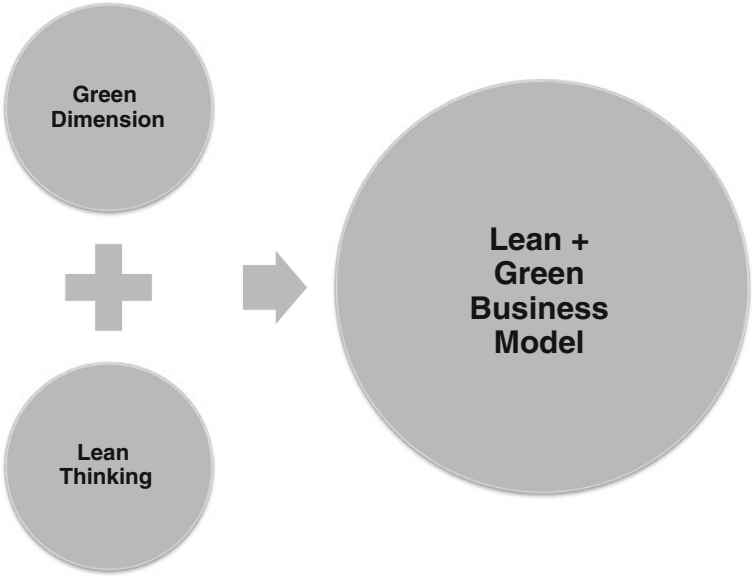

Fig. 1 The main objective of the study

To contextualize the subject and support the problem definition, this paper will be answering the following research questions:

- Can lean manufacturing practices be adapted and used as a strategy to achieve business environmental sustainability?
- What different frameworks and corporate strategies are needed to support the three sustainability dimensions?

In order to create the basis for the L&GBM, this paper explores some of the fundamental building blocks of lean thinking with sustainability and green concepts. It proposes the model structure and dynamics. The paper also reports the structure of the new model, considering purpose, principles and ways of working, discussing why it is different from pure green and pure lean thinking.

Action research or participatory action research is a reflective process of progressive problem solving led by individuals working with others in teams, or as part of a community of practice, to improve the way they address issues and solve problems. Action research involves the process of actively participating in an organization change situation whilst conducting research. Action research can also be undertaken by larger organizations or institutions, assisted or guided by professional researchers, with the aim of improving their strategies, practices, and knowledge of the environments within which they practice. As designers and stakeholders, researchers work with others to propose a new course of action to help their community improve its work practices. According to Gill (2009) an action research type of study is developed in seven steps: (1) exploratory phase, (2) understanding the problem, (3) defining the hypothesis, (4) project scope, (5) data collection and (6) analysis of results. Figure 2 presents the basic framework for the research structure.

The analysis of the key findings and improvement opportunities related to the application of the L&GBM were developed in five different moments. Each of these moments was called an improvement cycle. The objectives of developing these improvement cycles are:

- Analysis of kaizen results in terms of (1) reduction of environmental impact, (2) increase the productivity in the use of resources;

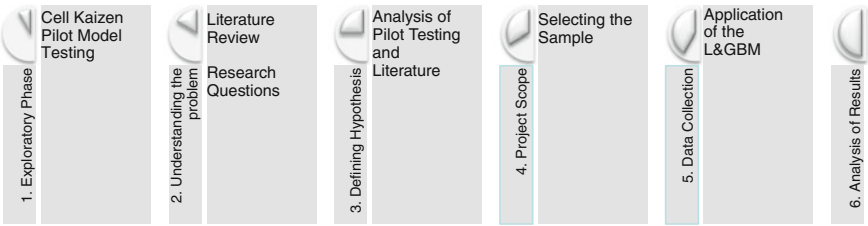

Fig. 2 Research structure applied for the development of the L&GBM. *Source* Developed by the authors

- Analysis of action plan results in terms of cost reduction;
- Confirm model prerequisites;
- Identify other key findings;
- Identify model improvement opportunities.

In this study the L&GBM model was developed, tested and improved through a series of iterative testing cycles and the analysis of the results of each cycle. Two methods were applied for developing these analyses: (1) Brainstorm sessions with participants and specialists and (2) A3 analysis. Brainstorming is a group creativity technique by which a group tries to find a solution to a specific problem by gathering a list of ideas spontaneously contributed to by its members. Brainstorming was developed and coined by Osborn (1963) through the book Applied Imagination. A3 is a structured problem-solving approach developed by Toyota for training of engineers, supervisors and managers. The term A3 derives from the paper size used for the report, which is the metric equivalent to 11 × 17 paper. Toyota actually uses several styles of A3 reports: for solving problems, for reporting project status, and for proposing policy changes. The A3 process helps people engage in collaborative, in-depth problem solving. It drives problem-solvers to addressing the root causes of problems, which surface in day-to-day work routines (Sobek II and Smalley 2008).

2 Problem Definition

In order to contextualize the subject and support the problem definition, this paper discusses the fundamental building blocks of the research, such as the (2.1) *the fundamental aspects of lean thinking,* (2.2) *the basis for green thinking and* (2.3) *the integration of lean and green to develop a model for sustainable manufacturing.* This paper forwards the following propositions:

- The application of pure lean promotes environmental improvement even though there is no direct intention to reduce environmental impact.
- There are several examples describing the synergy between lean and green practices but none, so far, have proposed a different way of thinking.
- Most frameworks and corporate strategies do not fully contribute to the core sustainability dimensions.
- Pure lean thinking contributes to two sustainability dimensions—(1) profit and (2) people.
- A new way of thinking can be created by integrating one further dimension—(3) the planet to pure lean thinking.

2.1 The Fundamental Aspects of Lean Thinking

Manufacturing is the constant game of doing more with less (Hopp and Spearman 2008). Therefore, lean thinking is one of the improvement strategies that have completely changed the way manufacturing has developed over the past decades. Gordon (2001) states that for decades, lean manufacturing has been considered the best way to run a manufacturing company.

According to Bicheno (2000) the general purpose of lean thinking can be described in three main dimensions (1) Quality, (2) Delivery and (3) Cost. It means that, producing exactly what the customer wants, exactly when (with no delay) at fair price and with minimum waste is the ultimate goal of a lean enterprise. Therefore, lean thinking focuses on the optimization of production resources oriented by the customer—time, people, machine, space, etc., and consequently reduces wastes. Thus, Lean Thinking contributes to the economic, or profit, dimension of sustainability. In general terms, lean thinking is defined and described by five key principles (Womack and Jones 1996):

- *Specific value*: define value precisely from the perspective of the end customer in terms of the specific product with specific capabilities offered at a specific time;
- *Identify value streams*: identify the entire value stream for each product or product family and eliminate waste;
- *Make value flow*: make the remaining value creating steps flow;
- *Let the customer pull value*: design and provide what the customer wants only when the customer wants it;
- *Pursue perfection*: strive for perfection by continually removing successive layers of waste as they are uncovered.

Resource productivity and closed loops provide better services, for longer periods, with less material, cost and hassle. The logic of lean thinking, with the emphasis on eliminating the classic seven wastes (Ohno 1988), makes a customer-defined value flow continuously with the aim of producing less waste. Together these practices offer the foundation for a powerful new business logic: Instead of simply selling the customer a product, it is perceived appropriate, to derive what is desired, considering the quantity, rate and timeliness. Based on the analysis of customer value, lean presents a set of tools and techniques for continuously improving processes and eliminating wastes (Rother and Shook 2003).

Due to the relentless drive to reduce all forms of waste, including defects, over-processing and unnecessary transportation lean contributes to environmental, or green thinking, inadvertently and this paper supports the proposition that:

- *The application of pure lean promotes environmental improvement even though there is no direct intention to reduce environmental impact.*

Table 1 Two major Kaizen objectives

Objectives	Description
Develop a problem solving culture	With a focus on analysis and problem solving by applying scientific and structured thinking. Lean philosophy presents a variety of tools and techniques with the ultimate goal of improving processes and eliminating wastes. Developing a problem solving culture is key for deploying the lean thinking (Berger 1997)
People involvement	Kaizen relies on ongoing effort and engagement of people - it is based on the constant effort for involving and integrates people, from the shop-floor workers to the senior executives. For lean thinking the key for success is based on the capacity for training and involving everyone. Based on this idea, human-systems are considered more successful than software systems for sustaining the results. This creates a learning environment, with long term maintenance of results and openness for creativity and improvements (Berger 1997)

According to Womack and Jones (1996) one of the key building blocks of lean thinking is Kaizen—a process-oriented philosophy that focuses on incremental improvements and standardization of the improved system as the building block for further improvement. Table 1 describes the two major objectives of the Kaizen (Berger 1997):

Whilst Bicheno (2000) considers that lean is described in the QCD dimensions, Hines et al. (2004) argues that pure lean thinking not only focuses in one dimension of sustainability, (1) profit, but also supports another , the (2) people dimension. Considering scientific methods and the involvement of people as the basis for its tools and techniques, lean presents a robust methodology for incorporating the social, people dimension in a system thinking approach. In addition, 'Respect for People' is a key concept of TPS (Sugimori et al. 1977) suggesting that the well being of employees and their involvement in the process improvements is also central to lean. The soft issues of lean, which links the importance of people to the ability to sustain long-term competitive advantages, has been demonstrated in a number of studies (Beale and Found 2006; Carleysmith et al. 2009; Found et al. 2006; Lander and Liker 2007; Liker 2004; Liker and Meier 2007; Liker and Hoseus 2008; Liker and Convis 2012; Mann 2005). Therefore, according to the authors, pure lean thinking contributes to two dimensions of the sustainability concept, such as:

Full contribution to the profit dimension due to its core focus in eliminating the seven classic wastes and reducing costs and;

Partial contribution to the people dimension, due to its focus on the Kaizen continuous improvement philosophy for solving problems and involving people, therefore this paper proposes that:

- *Pure Lean Thinking contributes to two sustainability dimensions*—(1) *profit and* (2) *people.*

2.2 Basis for Green Thinking

Green Thinking is rooted in sustainability, which is a systemic concept relating to the continuity of economic, social and environmental aspects of human society. It is however part of a wider and evolving field of corporate social and environmental responsibility, which in modern times has its origins in Rachel Carson's Silent Spring (Carson 1965) and the Club of Rome's 'Limits to Growth' analysis (Meadows et al. 1972). The term was first used in 1987 by the Brundtland Commission, which coined what has become the most often-quoted definition of sustainable development:

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED 1987).

The field of sustainable development can be conceptually broken into three constituent parts: environmental sustainability, economic sustainability and socio-political sustainability. Figure 3 presents a representative scheme of sustainable development vectors.

Sustainable development ties together concern for the carrying capacity of natural systems with the social challenges facing humanity (Zokaei et al. 2010). Therefore it contains two key concepts: (1) the concept of needs, in particular the essential needs of the world's poor, to whom overriding priority should be given; (2) the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs. All these definitions of sustainable development propose understanding the world as a system —a system that connects space and time. Therefore, the concept of sustainable development is rooted in systems thinking (Lovelock 1990).

Sustainability is a big umbrella term addressing a host of issues (Hall 2010) not all of which are limited to environmental, or 'Green' issues. Many writers emphasize only a few aspects of sustaining the planet in a condition to support life, but the scope of concerns is so broad that it's difficult—or impossible—to think

Fig. 3 Sustainable development vectors. *Source* Adapted from Elkington (1997)

about them all at the same time. Consequently, an abundance of separate initiatives attack some aspect of sustainability; local recycling, alternative energy ventures, permaculture, green building codes, etc.

2.2.1 Dimensions of Green Thinking

Over the past decades, many different corporate strategies were created proposing the co-existence of industry, the business, the people, the natural environment and their interactions in systems thinking approach. Zokaei et al. (2010) provides an overview of some of these key management strategies proposed to pursue sustainable development, such as Industrial Ecology (Nielsen 2007; Tibbs 1992), Industrial Symbiosis (Boons et al. 2011), Eco-efficiency (Korhone 2007), Triple Bottom Line (Elkington 1997; Lenzen 2008), Natural Capitalism (Robèrt 2002a; Hawken et al. 1999), The Natural Step (Robèrt 2002b).

In fact, the difficulty to make the concept of sustainability and its application clear is such that many researchers have explored it deeper. Glavic and Lukman (2007) present a study that summarizes the definition of sustainability and its terms. The Stern Review (Stern 2007) explored the economics of climate change. Lozano (2008) identifies the need for many to fully understand the concept, presenting a study that not only expand the concept of sustainability but also clarifies its dimensions. In a second study Lozano (2012) presents research that discusses how company's voluntary sustainability initiatives contribute to the sustainability dimensions. Table 2, adapted from Lozano's study, presents a list of these sustainability/corporate strategies and how they contribute to the sustainability three core dimensions of (1) Economic (Profit) (2) Environment (Planet) and (3) Social (People). With different structure and priorities, all these strategies describe conditions for sustainable systems and propose strategies in order to make sustainable development concept viable.

The conclusion on analyzing Table 2 is that, although all these concepts have been around for much of the last 20 years, most of the sustainability/corporate strategies have focused mainly on environmental conservation and compliance. The majority, as they are proposed, are not integrated, or part of, the fundamental building blocks of the manufacturing strategies that are pro-active in all dimensions of sustainability.

Therefore, following this idea it is possible to conclude that:

- *Lack of existence sustainability/corporate strategies that are able to contribute to the core three dimensions of sustainability* (*people, profit and planet*) *and that are fully integrated to the main aspects of the business.*

Table 2 Examples of sustainability/corporate strategies and its contribution to the sustainability dimensions

Sustainability/corporate strategies	Sustainability dimensions		
	Profit/economic	Planet/ environment	People/social
Sustainable livelihoods	*Full contribution*	*Full contribution*	*Full contribution*
Triple bottom line	*Full contribution*	*Full contribution*	*Full contribution*
The natural step	Partial contribution	*Full contribution*	Partial contribution
Environmental management system	None	*Full contribution*	None
Environmental and social accounting	*Full contribution*	*Full contribution*	*Full contribution*
Life cycle analysis	None	*Full contribution*	None
Cleaner production	*Full contribution*	*Full contribution*	None
Design for environment	None	*Full contribution*	None
Eco-efficiency	*Full contribution*	*Full contribution*	None
Industrial ecology	*Full contribution*	*Full contribution*	None
Factor X	Partial contribution	*Full contribution*	None
Green chemistry	None	*Full contribution*	None
Corporate social responsibility	None	Partial contribution	*Full contribution*
Sustainable reporting	*Full contribution*	Partial contribution	Partial contribution
Corporate citizenship	None	None	*Full contribution*

Source Lozano (2012)

2.3 Integrating Lean and Green Thinking

Lean sees waste as anything that is non-value added to the customer (Bicheno 2000). In the other hand, Green sees waste as extraction and consequential disposal of resources at rates, or in forms, beyond that which nature can absorb (Lozano 2008). An environmental waste is an unnecessary, or excessive, use of resources or substances released to the air, water, or land that could harm human health or the environment (EPA 2006). Environmental waste can occur when the company uses

resources to provide products or services to customers and/or when customers use and dispose of products (EPA 2006).

There has been debate in the literature whether improving environmental performance would undermine the economic sustainability of an organization and that many businesses could not afford the cost of meeting their environmental responsibilities (Florida 1996; Found 2009). However, there are many examples where improving environmental performance has improved the company's profit (Maxwell et al. 1993; Porter and van der Linde 1995; King and Lenox 2001; Cobert and Klassen 2006; Yang et al. 2011).

The US Environmental Protection Agency (EPA 2006) developed this theme and has reported some key findings: (1) Lean produces an operational and cultural environment that is highly conductive to waste minimization and pollution prevention; (2) Lean can be leveraged to produce even more environmental improvement; (3) Some regulatory friction can be encountered when applying lean to environmentally-sensitive processes; (4) Environmental agencies have a window of opportunity—while companies are embarking on lean initiatives and investments—to collaborate with lean promoters to further improve the environmental benefits associated with lean.

Two recent studies discuss the synergies between pure lean thinking and environmental improvement practices. In the first, Biggs (2009) focused on the integration of lean thinking and environmental improvement. Some of the most important findings she reported were:

- Traditional approaches to lean is capable of providing environmental benefits even though there is no direct intention to reduce environmental impact;
- The lean methodology can be used to make environmental improvements as well as productivity improvements;
- Kaizen/Continuous Improvement (CI) Kaizen blitz and workforce involvement and suggestions are popularly suggested methods of gaining environmental benefit from a Lean implementation;
- It is the culture of waste elimination and experimentation, problem solving and improvement of best practice encouraged by lean that may help companies make environmental improvements;
- A lean approach can help make the business case for environmental impact reduction.

In a second study, Dues et al. (2012) discuss how lean practices are catalysts for greening operations. The authors discuss that the lean and green connection goes beyond the idea of waste reduction, overlapping in paradigms such as (1) tools and practices, (2) supply chain relationship, (3) lead time reduction, (4) focus on people and organization (5) use of techniques for waste reduction. The research findings indicate that green comes as a natural extension to lean as most of lean practices are green without the explicit intention to be green and concludes that lean manufacturers are greener than non-lean companies.

Following these two studies is possible to conclude that:

- *Lean thinking serves as a catalyst to green thinking.*
- *Lean can be the first stage for a company to become green.*

In fact, over the past two decades the lean community has focused on operational improvements to build a continuous improvement. In the lean model, work is based on the principles of continuous improvement, or Kaizen. Workers are responsible for identifying problems found on the production line and, in contrast to mass production, are able to stop the line for such problems. Floor workers are arranged in teams, with a team leader performing a coordinating role in addition to assembly tasks (Rothenberg 2001). A benefit of pollution prevention activities is that they are often value added for the firm since they reduce costs through material use reduction or through the avoidance of waste management costs (Florida 1996; Found 2009).

The next challenge for the lean community is to consciously account for the environmental issues. Gordon (2001) discusses some ways for integrating lean and green practices with a focus on cost reduction practices. The fundamental building block of lean thinking is continuous improvement, Kaizen, with its focus on problem solving and employee involvement fits with the notion of creating a greener industry. Therefore, the pursuit of continuous improvement, i.e. Kaizen, creates substantial opportunities for pollution prevention and waste and emissions reduction. Figure 4 illustrates the positioning of Lean and Green Manufacturing.

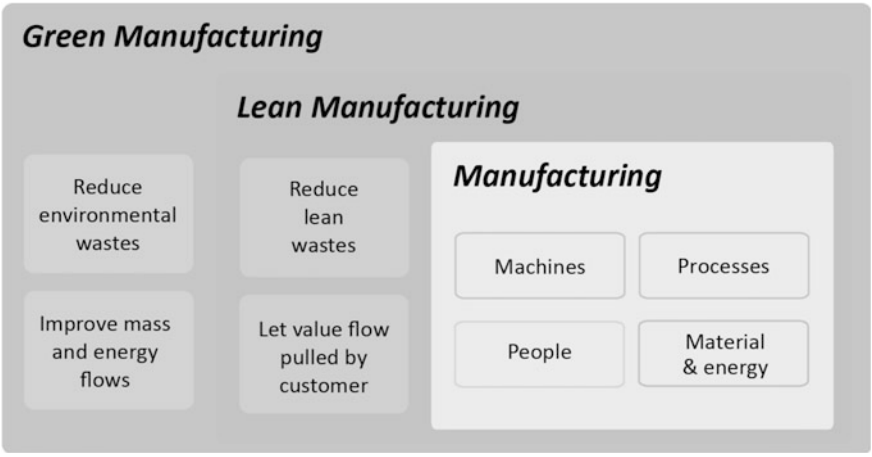

Fig. 4 Level of integration of lean and green with manufacturing processes. *Source* Developed by the authors

2.3.1 Integrating Lean and Green in Practice

Although the idea of lean thinking had not been fully explored by many in the environmental community, a number of articles were published where some of the lean thinking fundamentals, such as the need for people involvement (Venselaar 1995; Boyle 1999; Stone 2000; Remmen and Lorentzen 2000; Perron et al. 2006) the idea of learning by doing (Dieleman and Huisingh 2006) continuous improvement (Fresner 1998) and application of problem solving tools (Calia et al. 2009) were identified as necessary for implementing environmental policies by environmental researchers indicating a connection between lean and green practices.

To the environmental researchers that recognized the existence of lean thinking, there have been several initiatives discussing positive and negatives aspects of using lean to support the other dimension of sustainability, the environment, using different aspects and tools of lean for solving environmental problems and therefore contributing to a more sustainable business. For example, Chiarini (2014) identified that whilst Value Stream Mapping, TPM and other lean tools such as 5S and cellular manufacturing were positively associated with reducing environmental impact, there were no significant environmental savings as a result of Single Minute Exchange of Die (SMED). This raised an interesting debate on the typology of lean tools for different environmental impacts; similar to the Hines and Rich (1997) argument that there is a typology of Value Stream Mapping tools to identify production wastes.

Vais et al. (2006) in the study 'Lean and Green at a Romanian secondary tissue paper and board mill', present the development of technical environmental projects for accomplishing legal requirements and the use of lean tools, such as 5S's, Kaizen and autonomous maintenance for developing punctual improvements, optimizing the use of natural resources and production output.

EPA published The Lean and Environmental Toolkit in December 2006 (EPA 2006) to demonstrate that traditional lean tools can be applied to environmental wastes. This manual establishes guidelines for using existing lean tools for improving material flow to reduce the main flows that support the production process and that can affect the environment (such energy, chemicals, wastes, etc.).

Following these studies is possible to conclude that:

- *There are intrinsic linkages between lean and green—not least due to the relentless focus of lean on waste elimination.*
- *Lean tools and fundamentals are successful when used for promoting environmental improvements.*

According to Gustashaw and Hall (2008) an organization in which lean is already at the heart of its business system, and Kaizen the basis for continuous improvement culture, could adopt the same strategy for improving production energy and material flows. Deploying a lean strategy of improving the way that products and materials are sourced, manufactured, marketed and disposed of at the end of its life-cycle means that lean thinking can be used for creating a sustainable manufacturing. The authors state that by applying lean logic, for thermodynamic environmental improvement

of mass-energy balances, the holistic improvement within a factory system boundary can benefit an existing business model greatly. Although this idea was stated by the Gustashaw and Hall (2008), no examples where found where pure lean thinking was expanded to create a new and integrated way of thinking. The examples found focus only on using and applying lean tools for promoting environmental improvement.

This idea of the existence of a new way of thinking, connecting the business thinking (such as lean) and the green dimension can also be sustained by analysing some pure green practices. Many researchers studied and proposed integrated approaches. Some of them explore the context of green manufacturing whilst others explore some limitation and success factors of cleaner production, pollution prevention initiatives expressing the need for a strategic approach, leadership support and integration into the existing business models. Table 3 presents a list of examples.

Building upon the existing work, some of the conclusions are:

- *Although lean and green integration was proven by many practical examples* (*Vais et al.* 2006; *EPA* 2006) *none of these have explored the idea of creating a new way of thinking.*

2.3.2 Dimensions of Lean and Green

Three components make up the 'triple bottom line' of corporate sustainability, a concept coined by Elkington (1998) which can be defined as meeting the needs of a firm's direct and indirect stakeholders (such as shareholders, employees, clients, pressure groups, communities etc.) without compromising its ability to meet the needs of future stakeholders as well (Dyllick and Hockerts 2002).

In 1999 Hawken, Lovins and Lovins discussed that there is a great potential of integrating lean thinking with its focus on QCD measures with environmental sustainability. Until recently lean manufacturing and the application of lean thinking has concentrated on the economic and some of the social aspects of sustainability. However, the essence of lean to produce more with less implies that lean thinking organizations use less resource, in the form of raw materials and energy. Therefore, lean thinking is green once it proposes the reduction of materials, wastes and energy that are required by the production; lean is creating a new manufacturing paradigm, which, inadvertently, includes an environmental sustainability element. Thus a Lean and Green Business Model makes this explicit and includes a deliberate, intended focus on reducing environmental impact that is measurable and forms part of a continuous improvement strategy.

According to Hall (2010) although lean thinking already explores some aspects of sustainability, people and profit, sustainability goes beyond this, including also the idea of environmental impact—mass and energy flows of everything that enters and leaves the system. Therefore, extending lean thinking to an integrated lean and green approach addresses the three core sustainability dimensions (people, profit and planet). A sustainable manufacturing business has to focus on eliminating wastes (profit) implementing Kaizen (people) and to explain the movement of mass

Table 3 Articles that explore the idea of integrated approaches to connecting business thinking (such as lean) and the green dimension

Key	Title	Authors	Year
Articles that propose the need of pollution prevention integration into existing systems	Cleaner production and profitability: analysis of 134 industrial pollution prevention (P2) project reports	Cagno et al.	2005
	Improving cleaner production by integration into the management of quality, environment and working conditions	Zwetsloot	1995
	New models of pollution prevention technical assistance	Atkinson	1994
Articles that explore the idea of integrated approaches to manufacturing—sustainable/ green manufacturing	A study of the environmental management system implementation practices	Hui et al.	2001
	Modeling manufacturing evolution: thoughts on sustainable industrial development	Baldwin et al.	2005
	Material flows and environmental impacts of manufacturing systems via aggregated input–output models	Xue et al.	2007
	An integrated methodology for environmental impacts and costs evaluation in industrial processes	Santos da Silva et al.	2009
	A system model for green manufacturing	Deif	2011
Articles that explore some limitations and success factors of cleaner production, pollution prevention initiatives expressing the need for a strategic approach, leadership support and integration into the existing business models	Comparative evaluation of cleaner production working methods	van Berkel	1994
	The essential elements for successful cleaner production programmes	Zwetsloot et al.	1996
	To make zero emissions technologies and strategies become a reality, the lessons learned of cleaner production dissemination have to be known	Baas	2007
	Cleaner production: beyond projects	Baas	1995
	Limitations of cleaner production programmes as organizational change agents I. Achieving commitment and on-going improvement	Stone	2006

(continued)

Table 3 (continued)

Key	Title	Authors	Year
	Limitations of cleaner production programmes as organizational change agents. II. Leadership, support, communication, involvement and programme design	Stone	2006
	Strategic sustainable development—selection, design and synergies of applied tools	Robèrt et al.	2002
	Scenarios in selected tools for environmental systems analysis	Höjer et al.	2008

and energy within and through boundaries (planet) even if these boundaries are only a production cell, the entire factory or the whole supply chain.

- *A new way of thinking can be created by integrating pure lean thinking* (1)—*profit and* (2) *people with the dimension of green thinking* (3) *planet*

Therefore, based on the discussion of the five propositions stated earlier, this paper aims to propose a new and integrated way of thinking that (1) contributes and balances the three sustainability dimensions (people, profit and planet) and that (2) integrates to the pure lean thinking one new dimension, the environmental sustainability, the green thinking, developing a model that uses the Kaizen approach for dealing and improving environmental flows of mass and energy in manufacturing environment that already possesses a deployment level in applying lean.

2.4 Beyond Sustainability

And what comes after sustainability? Compression thinking (Hall 2010) may answer this question. With a top-level statement that establishes a sure survival of life and promotes quality of life using processes that work to perfection with self-correcting, self-learning systems, without the use of excess resources. With no wasted energy, no toxic releases and always quality over quantity, compression thinking is based on the fact that the society is near a turning point, the end of expansion. Population is expanding on an earth with finite resources. Traditional thinking from the industrial revolution and financial thinking need to be changed. So, the case for compression is based on 4 main drivers (1) Finite Resources, (2) Precarious Environment, (3) Overconsumption, (4) Pushback, as discussed by Hall (2010).

According to Hall (2010) lean thinking breaks a little from traditional thinking since its practitioners are used to removing waste from processes, not always represented by costs. But compression thinking has to step beyond this. Physical

Fig. 5 The three vectors of sustainability viewed from compression thinking. *Source* Adapted from Hall (2011)

actions and their consequences must take priority over financial motivations. Therefore, compression begs for a fundamentally new economic thinking, looking beyond financial transactions to see the physical reality of what society and corporations do. Also, compression is not pure environmental. Environmental concerns are only one reason to make systemic changes. It calls for a different mind-set, for an integrated approach to deal with the increasing complexity of today´s work. Figure 5 shows how the three vectors presented by the sustainability concept are viewed based on compression thinking.

Following this, compression thinking brings a new way to see environmental issues. Differing from the sustainability concept, compression states that this should be part of bigger system, integrated into the core business model. Although compression has a much wider scope, it is understood that lean thinking is a way to get to compression.

3 The Lean and Green Business Model

In order to understand the purpose, the principles and the ways of working of the Lean and Green Business Model (L&GBM) and to explain why it is different than pure lean and pure green, the methodology section of this paper is divided four main blocks: The purpose of the model, (3.1); The principles of the model, (3.2); The ways of working of the model, (3.3) and why lean and green is different from pure lean or pure green thinking.

3.1 The Purpose of the Lean and Green Business Model (L&GBM)

Although, according to Bicheno (2000) the general purpose of lean thinking can be described in three main dimensions (1) Quality, (2) Delivery and (3) Cost, Lozano (2008), reviews the concept of environmental sustainability, established by several authors, and states that the green thinking can be quoted as the use of natural resources without going beyond the carrying capacities of the system and the production of pollutants without passing the biodegradation limits of the receiving system. Therefore, the general purpose of environmental thinking can be described in one dimension (Environment) with two main focuses: (1) Producing with the maximum productivity in the use of natural resources and (2) with the minimum environmental impact.

The idea of the L&GBM is using lean thinking to solve environmental problems, adding one more dimension to the traditional lean thinking, the Environment. In this context, the main objectives of the model are based on the fundamental building blocks of environmental sustainable practices:

- *Improving manufacturing processes resources productivity* by optimizing its supporting flows performance (materials and energy consumption and wastes generation);
- *Reduce manufacturing processes environmental impact*, by reducing all environmental wastes generated by production.

Following this, the L&GBM model can be defined as:

Producing exactly what the customer wants, exactly when (with no delay) at a fair price and with minimum waste and environmental impact by delivering the maximum productivity in the use of natural resources.

This means that lean and green thinking will be described in four dimensions, (1) Quality, (2) Delivery, (3) Cost) (4) Environment, linked to the three core sustainability dimension (1) Profit, (2) People and (3) Planet.

Figure 6 presents the position of L&GBM by locating it between pure lean and pure environmental thinking and illustrates how it integrates the sustainability vectors, in order drive towards compression. This begs fundamentally for a new economic thinking and calls for a different mind-set, for an integrated approach which deals with the increasing complexity of today's work.

3.2 The Principles of the L&GBM

In general terms, environmental thinking models, such as Industrial Ecology (Nielsen 2007; Tibbs 1992), Industrial Symbiosis (Boons et al. 2011), Eco-efficiency (Korhone 2007), Triple Bottom Line (Elkington 1997; Lenzen 2008), Natural

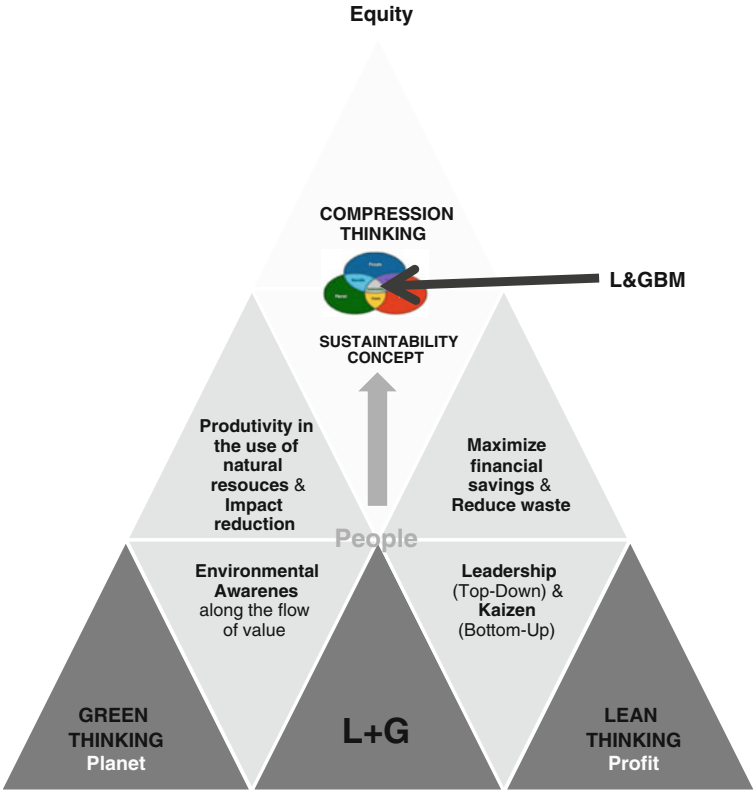

Fig. 6 Positioning the L&GBM

Capitalism (Robèrt 2002a; Hawken et al. 1999), The Natural Step (Robèrt 2002b) can be generalized by four common key principles:

- Identify environmental aspects and impacts;
- Measure environmental impact and the use of natural resources;
- Identify alternatives to reduce environmental impact and improve resource productivity;
- Continuous Improvement.

As stated previously, Womack and Jones (1996) offer five key principles for defining and describing lean thinking:

- *Specific value*: define value precisely from the perspective of the end customer in terms of the specific product with specific capabilities offered at a specific time;
- *Identify value streams*: identify the entire value stream for each product or product family and eliminate waste;
- *Make value flow*: make the remaining value creating steps flow;

- *Let the customer pull value*: design and provide what the customer wants only when the customer wants it;
- *Pursue perfection*: strive for perfection by continually removing successive layers of waste as they are uncovered.

To operationalize the lean thinking principles, the identification of value streams is key, to make value flow at the pull of the customer. In lean enterprises, manufacturing processes are organized in levels of flow, where:

- *The first level is the cell level*, the lowest production level in a manufacturing company organized by lean principals, composed by a finite number of operations/machines;
- *The second level is the factory level*, value stream level, composed by several cells that are part of the same value stream;
- *The third level is the extended value stream level*, composed by several sites (external supplier through to customer) that are part of the same value stream.

The leadership, methodology and execution patterns, designed for improving value stream performance in an organization that applies lean thinking as a strategy for increasing manufacturing performance, are used in the L&GBM. The difference here is that, instead of focusing in the flow of product (that is the main goal of improving manufacturing performance) the focus here is optimizing the use of the value stream supporting flows performance (mass and energy flows). Following this, the L&GBM can be described by five key principles:

- *Identify a stable value stream* (*VS*): Identify a stable value stream (level 1, 2 or 3). A stable value stream is a value stream that has improved and reduced the waste along the main dimensions of lean thinking (1) Quality, (2) Delivery and (3) Cost);
- *Identify the environmental impact* (*E*): Identify in the chosen value stream the environmental aspects and impacts;
- *Measure the environmental value streams* (*EVS*): Measure the value stream environmental impacts and the use of natural resources (the value stream supporting mass and energy flows);
- *Improve the environmental value streams* (*EVS*): Identify alternatives to (1) impact reduction and (2) resources productivity within the value stream;
- *Continuous Improvement* (*CI*): Set alternatives for improving the value stream supporting mass and energy flows.

Considering what was presented, Fig. 7 presents the overall idea of the L&GBM principles.

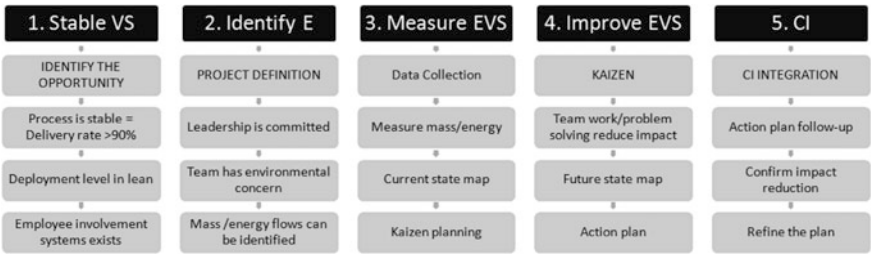

Fig. 7 The principles of the 5-step L&GBM. *Source* Developed by the authors

3.3 The Ways of Working of the L&GBM

The basic and most important idea of the L&GBM is that lean and green approaches will be integrated fully as part of the continuous improvement process of a manufacturing process, where the lean philosophy and ways of working were already in place, as described in the session 3.2. Following this, the objects of study of the L&GBM are the mass-energy flows of the manufacturing processes and the expected output for model application is the achievement of improvements in these thermodynamic flows (Materials, Chemicals, Water, Waste, Effluent, Energy) contributing to improvement of the overall performance.

One fundamental building block of lean thinking is continuous improvement, Kaizen, with its focus on problem solving and employee involvement, which fits perfectly with the notion of creating a greener industry. The L&GBM will be using the Kaizen approach for dealing and improving environmental flows of mass and energy of a manufacturing a cell and the value stream with the difference that here the focus is on optimizing the mass and energy flows.

3.4 Why the L&GBM Is Different Than Either Lean or Green Thinking?

Following the description of the L&GBM developed in sessions 3.1, 3.2 and 3.3, Table 4 highlights the fundamental differences of the L&GBM compared to pure green and pure lean thinking in terms of purpose, principles and ways of working of dealing of the sustainability vectors (People, Profit and Planet).

Considering what was presented in Table 4, L&GBM is different than pure *Green Thinking* due to:

- *L&GBM prioritizes the customer focus*: For being L&GBM it is necessary to be lean first; Therefore a prerequisite of deployment level in lean is key for Lean and Green;

Table 4 Table comparing Lean and Green with pure lean and pure green thinking

	Green environmental sustainability thinking	Lean lean thinking	L&GBM
General purpose	"Use of natural resources without going beyond the carrying capacities and the production of pollutants without passing the biodegradation limits of the receiving system" (Lozano 2008)	"Producing exactly what the customer wants, exactly when (with no delay), at fair price and minimum waste" (Bicheno 2000)	"Producing exactly what the customer wants, exactly when (with no delay), at fair price and minimum waste and environmental impact and the maximum productivity in the use of natural resources"
Main principals	1. Identify environmental aspects and impacts 2. Measure environmental impact and the use of natural resources 3. Identify alternatives to (1) impact reduction and (2) resources productivity 4. Continuous improvement	1. Specific value 2. Identify value streams 3. Make value flow 4. Let the customer pull value 5. Pursue perfection (Womack and Jones 1996)	1. Identify a stable value stream (level 1, 2 or 3); 2. Identify in the flow of value the environmental aspects and impacts 3. Measure value stream environmental impacts and the use of natural resources 4. Identify alternatives to (1) impact reduction and (2) resources productivity in value streams 5. Pursue perfection—continuous Improvement
People	1. Environmental awareness in all levels of the organization 2. High level of technical competence for people responsible for environmental impacts	1. Leadership (Top-Down) 2. Kaizen (Bottom-Up) People involvement and creation of solving problems culture	1. Leadership (Top-Down) 2. Kaizen (Bottom-Up) 3. Environmental awareness in along the flow of value
Profit	1. Equity (economic/environmental)	1. Maximize financial savings (revenue) 2. Reduce waste	1. Maximize financial savings (revenue) 2. Reduce waste (for all sources of wastes streams) 3. Equity (economic/environmental)
Planet	1. Productivity in the use of natural resources (mass and energy) 2. Environmental impact reduction (3R's)	None	1. Productivity in the use of natural resources (mass and energy) 2. Environmental impact reduction (3R's)

- *L&GBM identifies and measures environmental aspects and impacts based on value streams*: Traditional green thinking does not focus on the manufacturing ways of working to do this;
- *L&GBM focuses on a top-down and bottom-up approach*: for deploying environmental continuous improvements;
- *L&GBM prioritizes maximizing value and reducing costs*: It has an environmental approach, prioritizing financial savings and waste reduction as well.

Considering what was presented in Table 4, L&GBM is different to pure *Lean Thinking* due to:

- *L&GBM introduces into the traditional lean thinking a new dimension—the environmental concern aspect*: Traditional lean thinking focuses on three dimensions: Quality, Delivery and Cost. L&GBM introduces the environmental concern, requiring (i) minimization of the use of resources and (ii) reduction of environmental impact (iii) the need of environmental awareness along the flow of value;
- *L&GBM focuses on other sources of savings*: Traditional lean thinking considers only reduction of the seven classic wastes. With the introduction of the environmental variable concern along the flow of value, other sources of wastes may be focused and reduced, maximizing the overall savings.

The overall idea of the L&GBM encompasses the same principles of the lean thinking that are set in the house of lean, where the stability is the base, the Kaizen is it main pillar with the ultimate goal of improving performance, that in the case is based in three dimension, (1) Quality, (2) Delivery and (3) Cost. The difference here is that one more dimension, (E) Environment will be added to existing model. Figure 8 presents the idea.

Rich (2006) discusses lean improvement stages from chaos to control to competitive advantage, setting the natural steps to be followed by a manufacturing process implementing lean principles over a period of time. By concentrating first on stabilizing processes, where basic discipline, safety and morale is addressed and followed by improvements in quality, delivery performance and process flexibility, costs are reduced naturally, creating opportunities for further cost reduction that are realized in the later stages:

Process stability (Quality + Delivery + Flexibility) → Cost reduction

Perhaps, this logic does not take into consideration the other sources of cost that are part of the manufacturing process, the environmental wastes (materials and energy consumption and wastes generation) and that are not considered in the original Rich's model. Therefore, the L&GBM is built based on Rich's model, adding one extra variable to it:

Process stability (Quality + Delivery + Flexibility) + Environment → Cost reduction

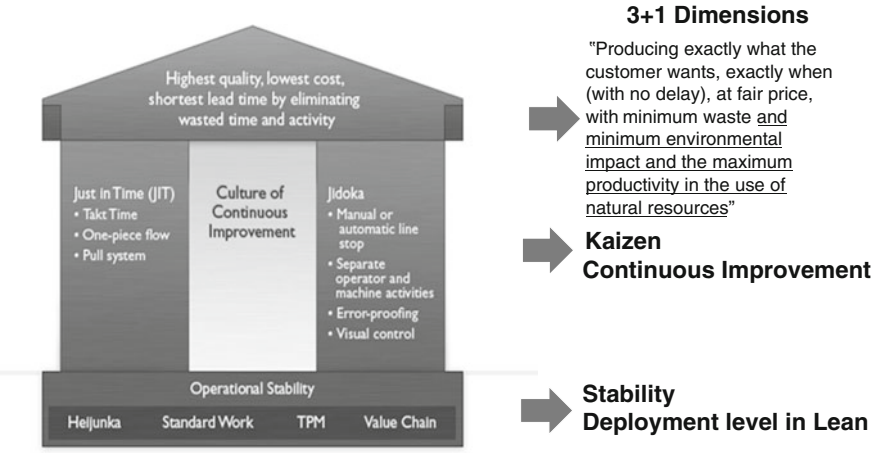

Fig. 8 The house of lean and L&GBM. *Source* Adapted from Rich (2006)

4 Results

The model was developed and implemented in a major, global engineering company that services the automotive and aerospace industries. Initially, the model was tested in two pilot cells in the automotive production plant in Brazil. These are termed Cell 1 and Cell 2 that represent two stages of the manufacturing process. Table 5 presents the basic characteristics of the manufacturing operational cells where the L&GBM was applied. The pilot Kaizen events were developed at the end of 2008 and 2010 and followed the five-step model. The Kaizen events each involved approximately 30 people, including all cell operators, leaders and managers, and maintenance people as well as environmental and lean specialists. The results of the Kaizen events are presented in Table 6. The main objectives of pilot testing were (1) confirm the 5 steps proposed and structure for the L&GBM for a cell before rolling it out for other several manufacturing cells of one manufacturing business, (2) confirm the prerequisites and participants, (3) analyze potential savings in terms of environmental improvements and cost reduction after applying the model, (4) identify model improvement opportunities, were all achieved. Therefore, the L&GBM for a cell was considered a good strategy for (1) improving manufacturing processes resources productivity by optimizing its supporting flows performance (materials and energy consumption and wastes generation) and for (2) reducing manufacturing processes environmental impact, by reducing all environmental wastes generated by production, the two main objectives of the L&GBM.

The action plans from both Kaizen workshops were not implemented totally because some of the ideas proposed by the Kaizen teams were considered not to be viable by technical experts following detailed technical analyses. However as

Table 5 Environmental and manufacturing characteristics of the pilot cells where the L&GBM was applied, including the application and evaluation of prerequisites

Manufacturing characteristics	Cell 1	Cell 2
Kaizen Date	November 08	Jun 10
Nature of operations	Steel machining	Assembly of manufactured parts
Main Cell Mass and energy flows	Energy Water Chemicals/oils Effluents Metallic waste Hazardous wastes	Energy Waste grease Hazardous wastes Cleaning cloths
Actual state data: energy and materials consumption and wastes generation	Energy consumption: 261 Mwh/month Water consumption : 1.4 m^3/month Chemicals usage : 0.6 m^3 /month Metallic wastes : 55 ton/month Hazardous wastes: 60 m^3/month	Energy consumption: 11 Mwh/month Waste grease: 0.2 ton/month Hazardous wastes: 3 m^3/month Cleaning cloths usage: 3120 units/month
Prerequisities		
Level of lean	Deployment level +	Deployment level +
Process stability	<90 % +	<90 % +
Application of employee involvement tools	In place +	In place +
Leadership support	High +	High +
Environmental awareness	In place +	In place +
Use of resources	High +	Medium -
Total cost of mass and energy flows (US$/Year)	1,005,000	483,500
Major impact in the Cell environmental cost	Metallic waste 68 %	Grease 75 %

Table 7 shows they were accepted substantially and generated significant benefits. Considering that the automotive company where the project is being tested has approximately 70 cells, if the model is implemented to the same extent in all cells, the L&GBM will generate a total annual savings of US$1,600,000/year for the company. Following the pilots, the L&GBM was then rolled out to other manufacturing cells. The rollout phase of the L&GBM was further developed in automotive manufacturing operations in Brazil in 2011. The model applied for this

Table 6 Results of Kaizen event: identification of improvement opportunities for the cell mass and energy flows

Cell impact	Cell 1	Cell 2
Energy saving (%)	8	6
General Chemical products consumption reduction (%)	91 (oils)	1 (grease in the product)
Water consumption reduction (%)	34	NA
Effluent generation reduction (%)	69	NA
Metallic waste generation reduction (%)	33	NA
Hazardous waste generation reduction (%)	67	45
Cleaning cloths Usage reduction (%)	NA	50
Grease waste generation reduction (%)	NA	100[a]
Average resources reduction (%)	50	40

NA not applicable
[a] 100 % waste elimination due to 100 % recycling of grease

Table 7 Implementation results

	Cell 1	Cell 2
% action plan implemented	94 %	81 %
Examples of improvement opportunity ideas that were identified during the Kaizen events that were implemented	*To reduce energy usage*: Motion sensitive and low energy lights were installed in low usage areas *To reduce metallic waste generation*: Forgings were redesigned for reducing machining and hence metallic waste *To reduce contaminated waste generation*: Plastic wrap containing oil contamination was eliminated from the containers—substantial savings in disposal costs	*To reduce energy usage*: All assembly cell lighting system was substituted to 54 W system that consumes less energy *To reduce grease waste generation*: (1) A new system was introduced to re-use the waste grease that was left in the used drums; (2) a new weighting standard was introduced in order to reduce the process waste grease
% Cost savings by reducing cell's mass and energy flows	13 % After implementing the action plans (1 year)	3 % After implementing the action plans (1 year)
Cost savings (US$/Year)	US$132,000 Results after implementing the action plans	US$15,000 Results after implementing the action plans

phase was unchanged from that applied previously. The Kaizen events followed the same structure as before. In total, through 2011, seven Kaizen events were held. Each of the seven manufacturing cells had different characteristics in terms of prerequisites for applying the L&GBM. The important point to highlight is that the pilot testing for the L&GBM was considered successful and it proved the business case for the L&GBM, confirming the proposed characteristics and prerequisites. The L&GBM was then rolled out to other manufacturing cells, including sisters' cells and for a value stream. Finally, it was applied outside of automotive and tested in plants in the US and UK.

5 Conclusions

Nature follows a distinct logic. From cradle to grave, the birth and death of every living thing, the composition of the atmosphere and the soil, the cycling of elements through air and waterways, and many other ecological assets are all the result of the evolution of living processes. The human species, while buffered against environmental immediacies by culture and technology, is ultimately fully dependent on the flow of ecosystem services and to the logic of the nature.

Manufacturing also has its own logic. In order to achieve competitive advantage, to be a lean enterprise, producing exactly what the customer wants, exactly when (with no delay) at fair price and minimum waste, the process of implementation follows a distinct logic: Cost reduction is ultimately fully dependent of stability, a function of quality, delivery and flexibility.

Lean and Green has its logic as well. In order not only to achieve competitive advantage but also to be a sustainable enterprise, producing exactly what the customer wants, exactly when (with no delay) at a fair price and with minimum waste and environmental impact by delivering the maximum productivity in the use of natural resources the process of implementation follows a distinct logic: To be lean and green it needs to first be a lean enterprise. It means that the lean and green thinking will be described in four dimensions, and not just three, (1) Quality, (2) Delivery, (3) Cost) (4) Environment, linked to the three core sustainability dimensions of (1) Profit, (2) People and (3) Planet.

L&GBM aims to (a) reduce environmental impact and (b) increase the productivity in the use of resources and observing the manufacturing structure, production flows and lean fundamental building blocks. Four key conclusions were identified while analysing the model. They are:

1. *L&GBM has a different purpose than traditional Lean or Environmental Thinking*: It introduces a new way of seeing environmental problems, (a) from the green side—prioritizing the customer focus, (b) From the lean side—including a new dimension in the traditional lean thinking—the environment.

2. *L&GBM covers the three dimensions of sustainability*: Since traditional lean thinking embodies two dimensions of sustainability (people and profit) L&GBM extends this and introduces another dimension to pure lean, the respect for the environment.
3. *L&GBM has a Lean to Green approach*: L&GBM application should be the continuation, a second step of a continuous improvement/lean culture already in place.
4. *L&GBM as an alternative approach to integrating environmental concern in operations management*: Since it uses lean fundamentals, L&GBM translates the environmental technical language to the manufacturing world.

In addition, the L&GBM shows that environmentally sustainable practices can be considered as an extension to a lean philosophy. Sustainability means meeting the needs of current generations without compromising the ability of future generations to meet their needs in turn. Three fundamental impacts, social, environmental, and financial (or People, Planet, Profit) evolved to define business objectives using the original Brundtland philosophy.

This concludes that lean leads us toward sustainability initiatives. Because it is much like lean in concept and practice, sustainability can be thought of as lean expanded to achieve a much broader objective. In a world of uncertainty about the economy and environment, where most corporate strategies do not contribute fully to the three pillars of sustainability, the L&GBM demonstrates the case for a new and innovative way of thinking for supporting the development and the evolution of a sustainable business.

References

Atkinson R (1994) New models of pollution prevention technical assistance. J Cleaner Prod 2 (2):101–106

Baas L (1995) Cleaner production: beyond projects. J Cleaner Prod 3(1–2):55–59

Baas L (2007) To make zero emissions technologies and strategies become a reality, the lessons learned of cleaner production dissemination have to be known. J Cleaner Prod 15(13–14):1205–1216

Baldwin J, Allen P, Winder B, Ridgway K (2005) Modeling manufacturing evolution: thoughts on sustainable industrial development. J Cleaner Prod 13(9):887–902

Beale J, Found P (2006) Human aspects of sustainable lean manufacturing: the relationship between employee attitudes, personality traits and behaviours. In: Proceedings of 16th international conference on flexible automation and intelligent manufacturing, 26–28 June 2006, vol 2. University of Limerick, Ireland, pp 1111–1117

Berger A (1997) Continuous improvement and Kaizen: standardization and organizational designs. Integr Manuf Syst 8(2):110–117

Berkel C (1994) Comparative evaluation of cleaner production working methods. J Cleaner Prod 2 (3–4):139–152

Bicheno J (2000) The lean toolbox. PICSIE Books, Buckingham, UK

Biggs C (2009) Exploration of the integration of Lean and environmental improvement. Ph.D. thesis, School of Applied Science, Cranfield University, UK

Boons F, Spekkink W, Mouzakitis Y (2011) The dynamics of industrial symbiosis: a proposal for a conceptual framework based upon a comprehensive literature review. J Cleaner Prod 19 (9–10):905–911
Boyle C (1999) Cleaner production workshops. J Cleaner Prod 7(1):83–87
Cagno E, Trucco P, Tardini L (2005) Cleaner production and profitability: analysis of 134 industrial pollution prevention (P2) project reports. J Cleaner Prod 13(6):593–605
Calia R, Guerrini F, Castro R (2009) The impact of six sigma in the performance of a pollution prevention program. J Cleaner Prod 17(15):1303–1310
Carleysmith SW, Dufton AM, Altria KD (2009) Implementing lean six sigma in pharmaceutical research and development: a review by practitioners. R&D Manage 39(1):95–106
Carson R (1965) Silent Spring. Penguin Books, London
Chiarini A (2014) Sustainable manufacturing-greening processes using specific lean production tools: an empirical observation from European motorcycle component manufacturers. J Cleaner Prod. doi:10.1016/j.jclepro.2014.07.080
Cobert C, Klassen R (2006) Extending the horizons: environmental excellence as key to improving operations. Manuf Serv Oper Manage 8(1):5–22
Deif A (2011) A system model for green manufacturing. J Cleaner Prod 19(14):1553–1559
Dieleman H, Huisingh D (2006) Games by which to learn and teach about sustainable development: exploring the relevance of games and experiential learning for sustainability. J Cleaner Prod 14(9–11):837–847
Dues C, Tan K, Lim M (2012) Green as the new lean: how to use lean practices as a catalyst to greening your supply chain. J Cleaner Prod 1:1–8
Dyllick T, Hockerts K (2002) Beyond the business case for corporate sustainability. Bus Strateg Environ 11(2):130–141
Elkington J (1997) Cannibals with Forks: the triple bottom line of 21st century business. Capstone, Oxford
Elkington J (1998) Cannibals with forks: the triple bottom line of 21st century business. Environ Qual Manage 8(1):37–51
EPA, United States Environmental Protection Agency (2006) The lean and environment toolkit. Available at: www.epa.gov/Lean. Accessed 17 Dec 2011
Florida R (1996) Lean and green: the move to environmentally conscious manufacturing. Calif Bus Rev 39(1):80–105
Found P, Beale J, Rich N (2006) A theoretical model for sustainable change. In: Proceedings of 16th international conference on flexible automation and intelligent manufacturing, 26–28 June 2006, vol 2. University of Limerick, Ireland, pp 1075–1082
Found P (2009) Lean and low environmental impact manufacturing. In: Proceedings of POMS 20th annual conference, Orlando, pp 126–130
Fresner J (1998) Starting continuous improvement with a cleaner production assessment in an Austrian textile mill. J Clean Prod 6(2):85–91
Gill A (2009) Estudo de Caso: fundamentação científica, subsídios para coleta de dados, como redigir o relatório. Atlas, São Paulo
Glavic P, Lukman R (2007) Review of sustainability terms and their definitions. J Cleaner Prod 15:1875–1885
Gordon P (2001) Lean and green: profit for your workplace and environment. Berrett-Koehler Publishers, San Francisco
Gustashaw D, Hall R (2008) From lean to green. AME Target Mag 24(5):6–14
Hall R (2010) Compression: meeting the challenges of sustainability through vigorous learning enterprises. CRC Press, Boca Raton
Hall R (2011) Compression thinking. In: Proceedings LERC annual conference 2011, Cardiff University, Lean Enterprise Research Centre, Cardiff, UK, pp 13–28
Hawken P, Lovins A, Lovins H (1999) Natural capitalism: creating the new industrial revolution. Little Brown & Company, Boston
Hines P, Rich N (1997) The seven value stream mapping tools. Int J Oper Prod Manage 17(1):46–64

Hines P, Holweg M, Rich N (2004) Learning to evolve: a review of contemporary lean thinking. Int J Oper Prod Manage 24(10):994–1011
Hui J, Chan A, Pun K (2001) A Study of the Environmental management System Implementation Practices. J Cleaner Prod 9(3):269–276
Höjer M, Ahlroth S, Dreborg K-H, Ekvall T, Finnveden G, Hjelm o, Hochschorner E, Nilsson M, Palm V (2008) Scenarios in selected tools for environmental systems analysis. J Cleaner Prod 16(18):1958–1970
Hopp W, Sperarman M (2008) Factory physics. McGraw-Hill, Irwin
King AA, Lenox MJ (2001) Lean and green? An empirical examination of the relationship between lean production and environmental performance. Prod Oper Manage 10(3):244–256
Korhone J (2007) From material flow analysis to material flow management: strategic sustainability management on a principle level. J Cleaner Prod 15(17):1585–1595
Lander E, Liker J (2007) The Toyota production system and art: making highly customized and creative products the Toyota way. Int J Prod Res 3:2681–2698
Lenzen M (2008) Sustainable island businesses: a case study of Norfolk Island. J Cleaner Prod 16 (18):2018–2035
Liker JK (2004) The Toyota way: 14 management principles from the world's greatest manufacturer. McGraw-Hill, New York
Liker JK, Meier DP (2007) Toyota talent: developing your people the Toyota way. McGraw-Hill, New York
Liker JK, Hoseus M (2008) Toyota culture: the heart and soul of the Toyota way. McGraw-Hill, New York
Liker JK, Convis GL (2012) The Toyota way to lean leadership: achieving and sustaining excellence through leadership development. McGraw-Hill, New York
Lovelock JE (1990) Hands up for the Gaia hypothesis. Nature 344(6262):100–102
Lozano R (2008) Envisioning sustainability three-dimensionally. J Cleaner Prod 16:1838–1846
Lozano R (2012) Towards a better understanding of sustainability into companies' systems: an analysis of voluntary corporate initiatives. J Cleaner Prod 25:14–26
Mann D (2005) Creating a lean culture: tools to sustain lean conversions. Productivity Press, New York
Maxwell J, Rothenberg S, Schenck B (1993) Does lean mean green? The implications of lean production for the environmental management. MIT working paper
Meadows DH, Meadows DL, Randers J, Behrens W (1972) The limits to growth. Universe Books, New York
Nielsen S (2007) What has modern ecosystem theory to offer to cleaner production, industrial ecology and society? The views of an ecologist. J Cleaner Prod 15(17):1639–1653
Ohno T (1988) Toyota production system: beyond large-scale production. Productivity Press, Oregon
Osborn AF (1963) Applied imagination: Principles and procedures of creative problem solving. Charles Scribner's Sons, New York
Perron G, Côté P, Duffy F (2006) Improving environmental awareness training in business. J Cleaner Prod 14(6–7):551–562
Porter M, Van Der Linde C (1995) Toward a new conception of environmental competitive relationship. J Econ Perspect 9(4):97–118
Remmen A, Lorentzen B (2000) Employee participation and cleaner technology: learning processes in environmental teams. J Cleaner Prod 8(5):365–373
Rich N (2006) Understanding the lean journey. In: Rich N, Bateman N, Esain A, Massey L, Samuel D (eds) Evolution of lean: lessons from the workplace. Cambridge University Press, Cambridge, pp 11–31
Robèrt K-H (2002a) The natural step story. Seeding a quiet revolution. New Society Publisher, Gabriola Island, BC
Robèrt K-H (2002b) Strategic sustainable development: selection, design and synergies of applied tools. J Cleaner Prod 10(3):197–214

Rothenberg S (2001) Lean, green and the quest for superior environmental performance. Prod Oper Manage 10(3):228–243
Rother M, Shook J (2003) Learning to see. Lean Enterprise Institute, Cambridge, MA
Silva P, Amaral F (2009) An integrated methodology for environmental impacts and costs evaluation in industrial processes. J Cleaner Prod 17(15):1339–1350
Sobek II DK, Smalley A (2008) Understanding A3 thinking: A critical component of Toyota's PDCA management system. CRC Poductivity Press, Boca Raton, FL
Sugimori Y, Kusunoki K, Cho F, Uchikawa S (1977) Toyota production system and Kanban system: materialization of just-in-time and respect-for-human system. Int J Prod Res 15 (6):553–564
Stern N (2007) The economics of climate change: the stern review. Cambridge University Press, Cambridge
Stone L (2000) When case studies are not enough: the influence of corporate culture and employee attitudes on the success of cleaner production initiatives. J Cleaner Prod 8(5):353–359
Stone L (2006a) Limitations of cleaner production programmes as organizational change agents. I. Achieving commitment and on-going improvement. J Cleaner Prod 14(1):1–14
Stone L (2006b) Limitations of cleaner production programmes as organizational change agents. II. Leadership, support, communication, involvement and programme design. J Cleaner Prod 14(1):15–30
Tibbs H (1992) Industrial ecology: an environmental agenda for industry. Whole Earth Rev Winter 4–19
Vais A, Miron V, Pedersen M, Folke J (2006) Lean and Green at a Romanian secondary tissue paper and board mill—putting theory into practice. Resour Conserv Recycl 46:44–74
Venselaar J (1995) Environmental training: industrial needs. J Cleaner Prod 3(1–2):9–12
Womack J, Jones D (1996) Lean thinking. Free Press, New York
World Commission on Environment and Development (OCED) (1987) Our common future. Available at: http://www.un-documents.net/wced-ocf.htm. Accessed on 17 Dec 2011
Xue H, Kumar V, Sutherland J (2007) Material flows and environmental impacts of manufacturing systems via aggregated input–output models. J Cleaner Prod 15(13–14):1349–1358
Yang M, Hong P, Modi S (2011) Impact of lean manufacturing and environmental management on business performance: an empirical study of manufacturing firms. Int J Prod Econ 129:251–261
Zokaei K, Martinez, F, Vazquez D, Evans B, Sarmadi K, Peattie K, Pampanelli A, Hines P, Trivedi N (2010) Best practice tools and techniques for carbon reduction and climate change: lean and green report. Lean Enterprise Research Centre, Cardiff University, Cardiff
Zwetsloot G (1995) Improving cleaner production by integration into the management of quality, environment and working conditions. J Cleaner Prod 3(1–2):61–66
Zwetsloot G, Geyer A (1996) The essential elements for successful cleaner production programmes. J Cleaner Prod 4(1):29–39