A Lean & Green Model for a Value Stream

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Abstract

Following the paper "A Lean & Green Model for a production cell", published by Journal of Cleaner Production in December, 2014 (Pampanelli et al., 2014), the main objective of this paper is to propose the extension of the Lean & Green Model for the second level of flow, the Lean & Green Business Model (L&GBM) for a value stream (VS), understanding its main characteristics and differences. Studies developed confirmed that traditional VS thinking (divided by product families) is not applicable for solving with environmental problems in a manufacturing environment. Following this finding, the L&GBM for second level flow was developed and tested in a single multi-national engineering company, including the results of the model application at the value stream level. Such findings confirm that the Lean & Green Model can reduce resources use in a VS level from 2 to 40% and save R$ 1,5Mi.

Keywords: *Lean, Lean and Green, Kaizen, Value Stream*

1. Introduction

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 itself of sustainable development was described in the late 80's, following The Brundtland Report, a report made by the World Commission on Environment and Development. It describes the growing global awareness of the enormous environmental problems facing the planet, and proposes a growing shift towards global environmental action. The concern about the sustainability encouraged the society to support the development of a significant number of corporate practice, 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. 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).

"…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 is being explored by manufacturing to increase performance. The logic of lean thinking, with the emphasis on eliminating the seven classic wastes (Ohno, 1988) can be redesigned and integrated to the sustainability systemic concept.

"…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 (Bass, 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, offer the foundation for a new business logic, where the pillars of sustainability, social, economic and environmental, can be understood by manufacturing and therefore support business goals, requirements and needs.

Following this discussion and as a continuation of the paper "*A Lean & Green Model for a production cell*", published by Journal of Cleaner Production in December, 2014 (Pampanelli et al., 2014), the main objective of this paper is to propose the extension of the Lean & Green Model for the second level of flow, the Lean & Green Business Model (L&GBM) for a value stream. In general term, this paper wants to investigate (1) what are the key difference of L&GBM for value stream comparing to L&GBM for a cell and (2) how can lean and sustainability concepts be integrated fully and put into practice in a value stream manufacturing environment.

2. Problem definition

In order to contextualize the subject, this paper reviews (2.1) the fundamental aspects of lean thinking, (2.2) why pure lean promotes environmental improvement (2.3) how pure lean thinking contributes to the sustainability dimensions.

2.1 The fundamental aspects of lean thinking

According to Bicheno, 2000, the general purpose of lean thinking can be described in three main dimensions (1) Q-Quality, (2) D-Delivery and (3) C-Cost. It means that, "producing exactly what the customer wants, exactly when (with no delay), at fair price and minimum waste" is the ultimate goal of a lean enterprise. Therefore, lean thinking focus on the optimization of production resources oriented by the customer – time, people, machine, space, etc, and consequently reduces wastes. In general terms, lean thinking is defined and described by five key principles (Womack & Jones, 1998):

- 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.

According to Womack and Jones (1998), 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.

2.2 Why pure lean promotes environmental improvement?

Lean sees waste as 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).

Two recent studies discuss the synergies between pure lean thinking and environmental improvement practices. Biggs (2009) developed a deep study focused in of the integration of lean thinking and environmental improvement. Some of the most important findings the author had were:

- Lean as it is 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 more recent research, Dues et al (2012), discuss how lean practices are catalysts for greening the operations. The authors discuss that lean and green connection go 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. It also concludes that lean manufacturers are greener than non-lean companies.

Following these two studies is possible to conclude that:

- Lean serves as a catalyst to green.
- Lean can be the first stage to a company became green.

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.

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 lean tools for improving material flow for 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 the heart of its business system, and Kaizen is the basis for continuous improvement culture, the same strategy could be expanded for improving production energy and material flows. Deploying a strategy of improving the way that products and materials are sourced, manufactured, marketed and disposed at the end of its life-cycle means that lean thinking can be used for creating a sustainable manufacturing. The author states that by lean logic, or thermodynamic environmental improvement of mass-energy balances, the holistic improvement within a factory system boundary can benefit greatly an existing business model. Perhaps, although this idea was stated by the authors, no examples where found were pure lean thinking was expanded to create a new and integrated way of thinking. The examples found focus only in using and applying lean tools for promoting environmental improvement.

2.3 How pure lean contributes to the sustainability dimensions?

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 one, the (2) people. Considering scientific methods and involvement of people as basis for its tools, and techniques, lean presents a robust methodology for incorporating the social, people dimension in a system thinking approach. Therefore, according to the authors, pure lean thinking contributes to two dimensions of the sustainability concept, such as:

> (1) Full contribution to the profit dimension due to its core focus in eliminating the seven classic wastes and reducing costs and;
>
> (2) Partial contribution to the people dimension, due to its focus on the Kaizen continuous improvement philosophy for solving problems and involving people.

In 1999 Hawken, Lovins and Lovins (1999) discuss that there is a great potential of integrating lean thinking with environmental sustainability. Lean is creating a new manufacturing paradigm, which includes an environmental sustainability element. Therefore, lean thinking is green once it proposes the reduction of materials, wastes and energy that are required by the production. 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.

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 flow of everything that enters and leaves the system. Therefore, based on lean thinking approach, to cope with the three core sustainability dimensions (people, profit and planet), a lean manufacturing business has to focus in eliminating wastes (profit), Kaizen (people) and also to explain the movement of mass and energy within and through boundaries (planet), even if these boundaries are only a production cell, the entire factory or the supply chain.

Therefore, this paper aims to propose a new and integrated way of thinking, a new model, L&GBM, that (1) contributes and balances the three sustainability dimensions (people, profit and planet) and that (2) ingrates 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 value stream environment that already possesses a deployment level in applying lean.

3. L&GBM FOR A VALUE STREAM – The Model

Value streams are the flow of material and information across multiple processes, so that individual process-level improvement efforts fit together as a flowing value stream, match the organization's objectives, and serve the requirements of external customers (Hopp and Spearman, 2008). In order to cope with lean thinking principles of (1) specify the value, (2) identify value streams, (3) make the vale flow, (4) let the customer pull the value and (5) pursue perfection, lean thinking organizations use value stream mapping. Value stream mapping is a lean manufacturing technique used to analyze and design the flow of materials and information required to bring a product or service to a consumer. At Toyota, where the technique was originated, it is known as "material and information flow mapping". It can be applied to nearly any value chain. Although value stream mapping is often associated with manufacturing, it is also used in logistics, supply chain, service related industries, healthcare, software development, and product development

The same idea of redesigning a value stream for improving flow is applied by the L&GBM to a value stream. The difference here is the focus. While traditional value stream application will be focused in fulfilling the client´s need, the one that buys or requests a finished good or a service, L&GBM will be focused also in preserving the environment. Therefore, the objective here will be to reduce environmental impact and improve the use of resources. As in the cell model (Pampanelli et al., 2014), the objects of study in the L&GBM for a value stream will be the supporting flows for production, mass and energy consumption and wastes generation. Because the end customer for a L&GBM for a value stream is the environment, there's an important difference to be considered.

For a manufacturing perspective, one factory or one location may have more than one product being produced. As a consequence, it may have more than one value stream, all of them co-existing in the same physical location. This is fine for a lean organization since it will mean that in this case the value stream analysis will need to be developed individually, by value stream, as well as the implementation of improvement opportunities. Lean views waste as non-value added to the customer. The lean boundary is generally defined by a value stream map. Lean promotes high efficiency within the boundary of the system as defined by a value stream map intent on minimizing non-value added. Lean promotes resource conservation inside that boundary, which may be the walls of a plant or may extend to supply chains (the lean path conserve resources in an environmental sense - fewer and shorter material moves, compacting space, improving process-they waste less material or energy doing things that really didn't need to be done).

Sustainability goes beyond this to include environmental impact. So, this very same approach cannot be applicable when the focus is the environment. As discussed, green thinking sees waste as extraction and consequential disposal of resources at rates or in forms beyond that which nature can absorb. Nature is symbiotic. The environmental impact of production process is dependent on the surrounding environment, the soil, the air, etc. Several value streams co-existing in the same location, same site, and physical place may have a completely different impact (systemic and synergetic) on the surrounding environment, than their individual impact. **Figure 1** presents a framework to express this idea.

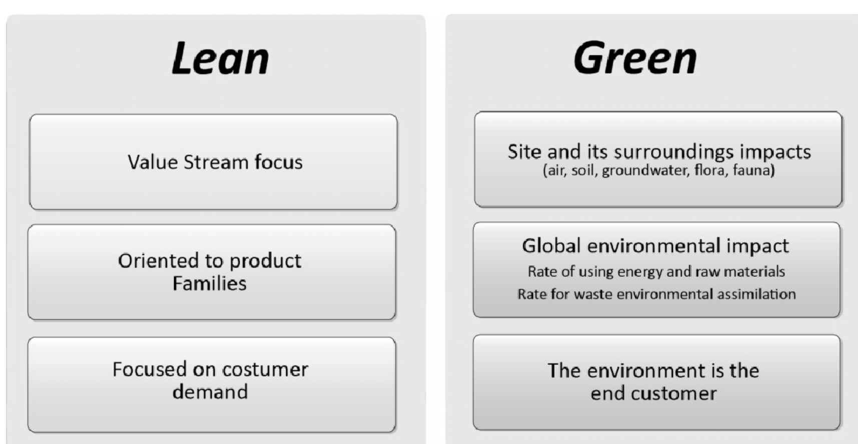

Figure 1: The L&GBM analysis of a value stream – In order to cope with the environmental principles the model considers all the value streams that compose one physical location.
Source: Developed by the author

The difference between original value stream analysis of a product and the overall site mass and energy balances applied by the L&GBM illustrate this difference in thinking. If several value streams co-exist in the same physical place and this is fine from an end customer point of view, in the case of the environment, that is synergic and dependent on the surrounding environmental conditions, the L&GBM for a value stream proposes the analysis of them all together, and thus considering the overall environmental impact for one specific site. This means that the mass and energy analysis of a value stream, one site, will not be divided by product families, it will be focused in analysis the overall impact to the end customer of this process that is the environment. The expected output of the L&GBM for a value stream is the degree of improvement in these thermodynamic flows and it will be focused in establishing strategies for (1) producing with the maximum productivity in the use of natural resources and with the (2) minimum environmental impact, but it will not be analyzing mass and energy flows of a factory oriented by product families. L&GBM to a value stream will be analyzing mass and energy flows of a factory having the environment as the end customer and so considering the analysis of its overall impact. Besides that difference, all the other characteristics of the L&GBM for a value stream are quite similar to the model presented for the cell (Pampanelli et al., 2014), the first level flow. The L&GBM to a value stream is applied to the second level flow, for the production step of the extended value stream, including all the value streams that co-exist in one manufacturing site and their surrounding impact on the environment. **Figure 2** presents this idea.

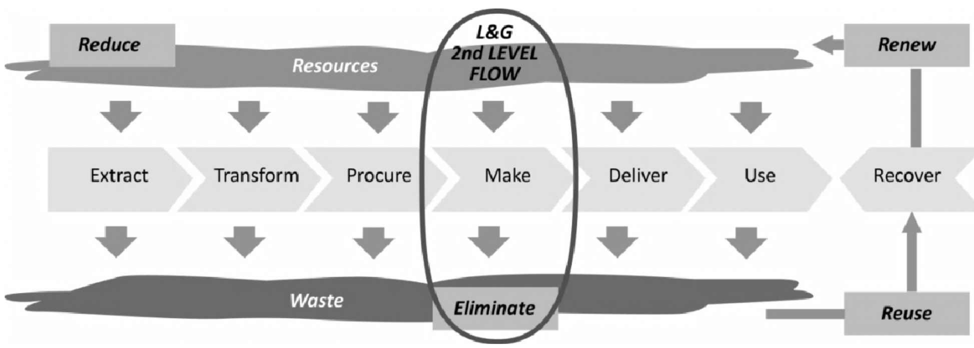

Figure 2: Boundaries of the L&GBM to a value stream
Source: Developed by the author.

Below is a description of the main prerequisites considered for a factory / value stream to be eligible for applying the L&GBM:

1. An overall stable process across all value streams, with delivery records over a 90%;
2. A mature deployment level in using and applying lean tools - for all value streams within the site;
3. Employee Involvement (EI) systems in place;
4. Supportive management team;
5. Factory is ISO 14001 certified and it is on its 2nd improvement cycle;
6. Factory has a significant use of resources (Materials, Chemicals, Water, Waste, Effluent, Energy);
7. Structure in place for environmental data collection.

Figure 3 represents the basic standard framework for L&GBM to a value stream.

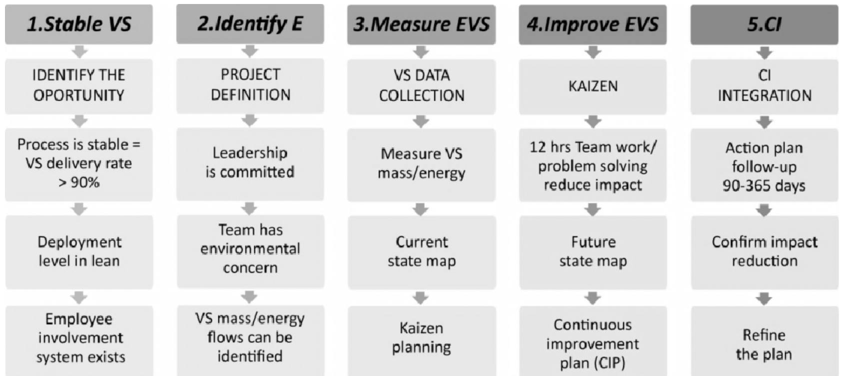

Figure 3: 5 Steps L&GBM for improving supporting flows performance in a factory.
Source: Developed by the author.

The general objective of each step is described as follows:

- Step 1 – Stable value stream (VS): Identify the need for improvement. Identify a site that copes with the prerequisites of the L&GBM for a value stream.

- Step 2 - Identify environmental aspects and impacts (E): Define the process improvement scope by identifying the environmental aspects and impacts of the value stream (in this case, the factory). Aspect and impact definitions are considered according to ISO 14001:2004. An environmental aspect is a feature or characteristic of an activity, product or service that affects or can affect the environment, the cell inputs or the cell outputs. An environmental impact is a change to the environment caused by environmental aspects resulting from cell inputs and outputs.

- Step 3 - Measure environmental value streams (EVS): Identify the actual data on the environmental process. Collect environmental data. Map 'As-Is', or current process and Identify the environmental process actual data for the whole site, analyzing the overall productivity in the use of resources and the site potential impact on the environment. Organize the Kaizen event. Draw project scope and align objectives for the improvement with the site plant manager and executive team. Define list of people to be involved, since this will require the involvement of several managers and specialists.

- Step 4 – Improve environmental value streams (EVS): Identify waste elimination opportunities during a Kaizen workshop. **Figure 4** presents the basic structure for the kaizen event applied by the L&GBM to a value stream.

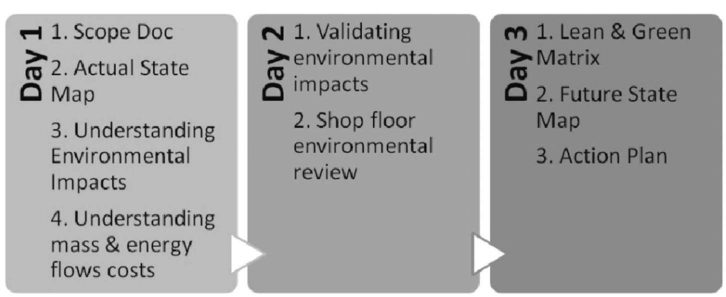

Figure 4: L&GBM to a value stream – Kaizen structure
Source: Developed by the author.

  - Day 1: About three hours for introduction, understanding the actual state, the costs and the environmental impacts of the factory mass and energy flows and for organizing the cross functional teams that will be responsible for each one of the supporting flows (energy, waste, water, chemicals, etc);

- Day 2: About six hours for team work shop floor exercise. The objective of each team is to understand the flow of use or generation of such resource during operation and its environmental impact. For this, the aspects and impact evaluation sheets from ISO 14001 are used. At the end of the exercise, a prioritization matrix is completed and it is possible to identify the production supporting flows that have more environmental impact as well as the parts, stages, cells that are responsible for the greatest resources usage and waste generation.

- Day 3: About three hours for consolidating the future state map for the mass and energy flows and action plan for the improvement opportunities as well as for prioritizing the cells that represent the greatest environmental impact and where the L&GBM for a cell should be applied (systemic approach). Map the 'To-Be', or future process, considering all the analysis developed, create the future map for the supporting production flows studied during the kaizen.

- Step 5 – Continuous improvement (CI): Develop action and communication plans in the Kaizen workshop. Sustainability of the results achieved in the kaizen through leadership standard work (LSW): Validate the action plan with leadership; Connection between action plan and the environmental management system (ISO 14001) objectives and targets. The L&GBM initiative will be key step in this process for establishing the site environmental diagnosis. The heart of the model is the identification of the process flows for the main environmental impacts, developed during the kaizen event. The improvement opportunities identified in the kaizen initiative will be integrated to the site continuous improvement plan and ISO 140001/EMS plans. The continuous improvement is sustained through management review of critical value streams and deployment of an environmental continuous improvement plans (CIP) for business strategic projects. The development of the improvement projects and the kaizens at the cell level will compose the operational building block of this cycle which will terminate, in every established period, in reviewing of overall environmental performance, cost savings and lessons learned by the period.

4. APPLYING THE L&GBM TO A VALUE STREAM

The application of the L&GBM to a value stream presented in this project was developed in manufacturing automotive firm in November 22nd , 2011, action plan was tracked along 2012 and 2nd level flow kaizen event was repeated on November 29th, 2012. **Table 1** presents the basic characteristics of manufacturing operations, including the evaluation L&GBM for VS prerequisites for the kaizens developed in 2011 and 2012.

Table 1: L&GBM for a VS – Project scope and analysis of prerequisites

Lean & Green Kaizen Project Scope		
Main products:	Precision forming parts, components and Half-shafts	
Nature of operations:	(1) Machining of parts (2)Painting of Shafts (3) Heat treatment of Components (4) Assembly (5) Precision forming (6) Phosphate treatment of forged parts	
Activities included in the value stream analysis:	(1) Machining (4) Assembly (5) Precision forming (6) Phosphate treatment	
Activities excluded of the value stream analysis:	(2) Painting (3) Heat treatment These two processes were excluded because they are two unique cells, therefore they will be treated separately, as in first level flow kaizens.	
Lean & Green Kaizen - Prerequisites		
YEAR	**2011**	**2012**
Dates of the Kaizens:	22/Nov/2011	29/Nov/2012

Sales in the period:	6.200.000 parts	6.400.000 parts
Annual tones of shipped parts:	57.197 Ton	59.038 Ton
Average Delivery rating (DAS):	92%	94%
Level of Lean:	Deployment	Deployment
Application of Employee Involvement Tools:	Deployment	Deployment
Cell/Site ISO 14001 Certification:	Since 2000 - 4º Cycle	Since 2000 - 4º Cycle
Data of the latest environmental training received by the site Team Members:	jul/11	jun/12
Site has an intensity use of resources?	YES	YES
Main supporting e-flows are cost intensive?	YES	YES
Data collection structure?	YES	YES

Table 2 presents the 2011 data and results for the mass and energy flows studied for the application of the L&GBM for VS.

Table 2: Data collected for mass and energy flows – 2011 period

	1. Electric Energy	**2. Metallic wastes**	**3. Water, machining chemicals and effluents**	**4. Oils and contaminated oils**	**5. Contaminated Wastes**
Main supporting flows description:	1. Electric Energy POA and CHQ	1. Metallic Wastes (Chips) 2. Scrap (Piercing, bars, others) 3. Metallic sludge	1.Water 2. Effluents 3. Cooling liquids	1. Oils (for machines, maintenance and protection) 2. Waste oils (POA and CHQ)	1. Contaminated Filter paper 2. Contaminated grease 3. Contaminated boots 4. General contaminated wastes (plastic, paper, others)
E-Flows - Physical Measurement	86.185 Mwh	12.739 Ton	**1. Water :** 112.467 m³ **2. Effluents:** 1: 2.310 m³ 2: 7.798 m³ 3: 1.445 m³ 4: 6.675 m³ **3. Cooling liquids** 1: 15.320 L 2: 51.695 L 3: 357.510 L 4: 93.556 L	**1. Oils:** 730.630 L **2. Waste oils:** 105.640 L	**1. Total contaminated waste:** 1.640 m³ + 35.610 **pieces**
Actual State Cost Results:	R$19,55Mi	R$44,81Mi	R$7,26Mi	R$3,734Mi	R$1,39Mi
Environmental Performance Indicators: **(e-flow / Tones of parts)**	1,506 Mhw/Ton	0,222 Ton /Ton	1,966 M³water/Ton 0,2 m³ effluent /Ton	12,77 L new oil /Ton	0,028 M³/Ton

The team of managers and specialists put together an action plan for each one of the mass and energy flows studied, with a total of 41 key strategic actions to be implemented, with a potential cost savings of R$ 2,32 million. The proposed plan was integrated at the site ISO 14001 system (EMS) / Continuous Improvement system. The plan was tracked along the entire year by the site top executives. Then the plan was reviewed again by the specialist. From the 41 actions proposed, 2 were cancelled since they were not considered feasible. Namely:

- **Metallic Waste VS:** Changing the tool for producing PF parts;
- **Oils VS:** Changing the oils controlling system.

From 39 actions that were considered viable to be implemented, 8 were implemented along 2012, representing 21% implementation and having direct cost savings of R$ 1,59 Mi. The actions implemented were:

- **Energy VS:** (1) Changing cold water pumping system; (2) Energy Reactive correction; (3) Implementing of a system for monitoring and control compressed air leakages;
- **Metallic Waste VS:** (4) Changing of cage design and VS;
- **Water / Chemicals VS:** (5) Changing PF lubricant system;
- **Oils VS:** (6) Implementing of internal oil regeneration system – with oil regeneration truck; (7) Implementing a system to re-use AIR oil;
- **Waste VS:** (8) Implement of automatic system for re-use of waste grease.

In order to confirm these results, a new round of data collection for 2012 period was developed. **Table 3** presents the 2012 data and results for the mass and energy flows of GKN Driveline Brazil manufacturing operations.

Table 3: Data collected for mass and energy flows – 2012 period

	1. Electric Energy	**2. Metallic wastes**	**3. Water, machining chemicals and effluents**	**4. Oils and contaminated oils**	**5. Contaminated Wastes**
Main supporting flows description:	1. Electric Energy POA and CHQ	1. Metallic Wastes (Chips) 2. Scrap (Piercing, bars, others) 3. Metallic sludge	1.Water 2. Effluents 3. Cooling liquids	1. Oils (for machines, maintenance and protection) 2. Waste oils (POA and CHQ)	1. Contaminated Filter paper 2. Contaminate grease 3. Contaminate boots 4. General contaminated wastes (plastic, paper, others)
E-Flows - Physical Measurement	**82.808 Mwh**	**12.395Ton**	**1. Water :** 114.410 m3 **2. Effluents:** 1: 1.749m³ 2: 7.820m³ 3: 1.044m³ 4: 5.120m³ **3. Cooling liquids** 1: 15.900L 2: 39.125L 3: 287.939L 4: 94.710L	**1. Oils:** 712.127 L **2. Waste oils:** 43.760 L	**1. Total contaminated waste:** 1.080 m³ + 42.450 pieces
Actual State Cost Results:	R$20,74Mi	R$41,52Mi	R$6,46Mi	R$3,731Mi	R$0,95Mi

Environmental Performance Indicators: **(e-flow / Tones of parts)**	1,40 Mhw/Ton	0,209 Ton /Ton	1,937 m³ water/Ton 0,15 m³ effluent /Ton	12,06 L new oil /Ton	0,017 m³/Ton

Table 4 presents the comparable results of cost and environmental indicators for 2011 and 2012 periods.

Table 4: L&GBM for VS - Comparable results of Cost and Environmental Indicators

	Energy	Metallic Wastes	Water & Effluents	Oils	Contaminated Wastes
2011 Cost	R$19,55Mi	R$44,81Mi	R$7,26Mi	R$3,734Mi	R$1,39Mi
2012 Cost	R$20,74Mi	R$41,52Mi	R$6,46Mi	R$3,731Mi	R$0,95Mi
% Improvement	**+6,1%**	**7,3%**	**11%**	**0,1%**	**32%**
2011 Environmental Performance	1,506 Mhw/Ton	0,222 Ton /Ton	1,966 m3 water/Ton	12,77 L new oil /Ton	0,028 m3/Ton
2012 Environmental Performance	1,40 Mhw/Ton	0,209 Ton /Ton	1,937 m3 water/Ton	12,06 L new oil /Ton	0,017 m3/Ton
% Improvement	**7%**	**6%**	**2%**	**6%**	**40%**

As can be observed in **Table 4**, environmental performance improved in all value streams after implementing L&GBM fora VS. Concerning cost, the only worse result was energy but in this case due to significant an increase of energy price rates (more than 20%). In fact, if the performance improvement due to L&GBM application was not made for the energy supporting flow, the result was going to be even worse. All the other four supporting flows, even with increase of price, the consumption reduction was so significant that all four had significant reduction in cost.

With this second round of data collection, a second L&GBM for a VS kaizen was developed in November 2012, involving about 30 people, a cross functional team consisting of technical experts and managers. In this new kaizen the results (environmental performance), projects and cost savings were reviewed, lessons learned were raised and evaluated and a new improvement plan was generated for the 2013 period.

The kaizen team proposed a plan of 30 actions to be tracked by top management along 2013, integrated to ISO 14001 system (EMS) / Continuous Improvement system. 19 actions are new actions, identified by the team during the last VS kaizen. 11 actions are originated from the 2011/2012 plan were kept by the team for the 2013 period.

The application of the model also identified the 3 main environmental costs of the company which are (1) Metallic, (2) Energy, (3) Water and Chemicals, proving that a preventive approach in terms of improving manufacturing processes resources productivity by optimizing its supporting flows performance (materials and energy consumption) would be a good strategy not only for reducing manufacturing processes environmental impact, but also for improving the operational financial performance.

The model also proves that integrating green with an operational approach can make businesses more competitive, saving R$ 1.590.000,00 and reducing environmental impact. Also, the model 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.

5. CONCLUSIONS

This paper has proposed a new model, the L&GBM applied to the value stream level, where the green concern for environmental sustainability is integrated with lean thinking. The model uses the kaizen approach for addressing and improving mass and energy flows in a manufacturing environment that already possesses a specified lean deployment level. Based on this, this paper focused on answering the following research questions:

1. What are the key differences of L&GBM for value stream comparing to L&GBM for a cell?

2. How can lean and sustainability concepts be integrated fully and put into practice in a value stream manufacturing environment?

For answering question one a deep analysis was developed considering characteristics and differences of L&GBM for a cell comparing to L&GBM for a value stream. Overall L&GBM application for 1st and 2nd levels of flow have different approaches: For first level flow, L&GBM for a cell is more dependent of lean (change agents) than environmental expertise, improvement actions are simpler. L&GBM for a value stream environmental focus is higher. It requires a higher level of environmental understanding and competence in order to develop the analysis, the kaizen and set the action plan. Also, traditional VSM thinking (divided by product families) is not applicable to the L&GBM: For the value stream analysis, for an environmental perspective, it should be a site based environmental impact and not only the impact of one value stream; there is a conjunction of environmental impacts that can create a system interference changing the overall impact; therefore traditional VSM thinking (divide by product families) is not applicable because it will not consider the overall impact in the surroundings and the combination of environmental effects.

For answering question two, a data analysis of the overall implementation was developed. In terms of reduction of environmental impact and productivity increase in the use of resources, the application of the L&GBM for a VS, comparing 2011 with 2012 environmental performance, confirmed VS improvement in terms reduction of environmental impact and increase in the productivity in the use of resources by 12%. In terms of cost reduction, at value stream level, 21% of implementation of the action plan, generated direct cost savings of R$ 1.590.000,00 and an overall mass and energy reduction (2011 x 2012) of 4,5%. All seven of model prerequisites were confirmed for the value stream level.

Based on the results presented, the L&GBM for a value stream shows that environmentally sustainable practices can be treated as an extension of lean philosophy. Environmental sustainability, like lean thinking, has a good track record of improving business finances because of the emphasis on eliminating waste. In a world of uncertainty about the economy and the environment, the L&GBM demonstrates a new and innovative approach to support the development of sustainable business.

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