Using BPM to improve sustainability in biomass generation

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Abstract
Biomass represents approximately 10% of the energy sources in the world. The most common use of biomass for energy is direct combustion, gasification, carbonization and pyrolysis. In this perspective, torrefaction emerges as a thermal biomass pre-treatment method that has an ability to reduce the major limitations of biomass, such as heterogeneity and lower energy density. However, one of the outputs from the torrefaction process is a pyrolysis condensate (tar). Tar is brown or black liquid composed of hydrocarbons which can cause clogging and fouling of pipes, heat exchangers or particulate filters. This paper provides a study performed in a biomass power generation company that was producing an excess of tar. In order to provide a solution to the excess tar generated, a framework to implement sustainability business processes using the Business Process Management (BPM) approach was used. The study found two solutions for the issue (short- term and long-term scenarios) using tools to improve the process management by focusing on sustainability.

Keywords
Business Process Management; Sustainability, Renewable Energy; Torrefaction;

Introduction

According to the 2010 World Energy Council, 10% of the energy in the world is generated from biomass. According to the Digest of United Kingdom Energy Statistics 2016 (DUKES) in 2015 25.3% of the renewable energy fuel used originated from (plant) biomass sources. According to the study 24.6% of the energy consumption in the UK came from renewable sources. Thus, it is possible to conclude that (plant) biomass energy represents 6.22% of the energy consumption in the UK, which represents an amount of 5.196,81 GWh.

Biomass is a sustainable versatile energy resource that can be converted into renewable energy carriers in solid, liquid and gaseous form (Nhuchhen et al 2014). According to Basu (2010), biomass has a special appeal in an environmental aspect because it makes no net contribution of CO_2 to the atmosphere. Regulations for making biomass economically viable are in place in many countries. In other words, if biomass replaces fossil fuels in a power plant, the latter could earn carbon credits that can be sold for additional revenue in countries where such trades are in practice.

As detailed above, Company A defines itself as an energy innovation company and uses torrefaction to transform wood into bio-char. According to Basu (2010), the most common use of biomass for energy is direct combustion, followed by gasification, carbonisation and pyrolysis. In this perspective, torrefaction emerges as a thermal biomass pre-treatment method that has an ability to reduce the major limitations of biomass including heterogeneity, low bulk density, low energy density, hygroscopic behaviour, and fibrous nature. Torrefaction aims to produce high quality solid biomass products (Nhuchhen et al 2014).

Company A is currently producing an excess of pyrolysis condensate (tar) as residue of the process. Tar can be defined as a mixture of water and organic compounds (Manattis et al, 2010). When cooled down or left in a jar for several days, a layer of high molecular weight compounds known as heavy tar is formed at the bottom. Tar can cause clogging and fouling of pipes, heat exchangers or particulate filters. As a result, tar formation and its control are still considered as one of the major challenges in the implementation of biomass gasification technology (Ruiz et al, 2013). Tar is listed at number 19999 from United Nations' list of dangerous goods (United Nations, 2015) and according to the CDC (2016), long term exposure to tar may cause lung, kidney and skin cancer.

Company A pyrolysis condensate is currently being collected by a third party company that charges £190 per 1000 L (1 IBC – $1m^3$). According to the organisation, in the last year approximately 95 IBCs of tar were disposed, which represents a cost of £18,050. The problem of the excess of tar is still presently bearable but is likely to increase in volume in the future. A Business Process Management (BPM) methodology will be used to solve the problem that Company A is encountering.

1. Literature Review

1.1. Sustainability

The sustainability topic has been discussed extensively in both academia and industry in the past decades (Elkington, 1997, United Nations, 1987, Slack, 2013, Gallotta et al., 2016). In 1987, the term sustainability and sustainable development became more prominent, through the publication of the Brundtland Commission's Report. The Brundtland Commission's Report defines sustainable development as 'the development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (United Nations, 1987). Nowadays, the term 'sustainability' is mostly used to refer to the best use of natural resources such as water and energy to meet the needs of the current population while at the same time being able to preserve the environment for future generations.

According to Elkington (1997), sustainability is an approach for managing businesses that draws on an integrated and balanced performance of the business's economic, environmental and social aspects. This concept is known as Triple Bottom Line (TBL). Slack et al. (2013) states that a sustainable business is one that creates an acceptable profit for its owners, by minimizing damage to the environment and enhancing the existence of the people with whom it has contact. Figure 1 represents the Triple Bottom Line framework.

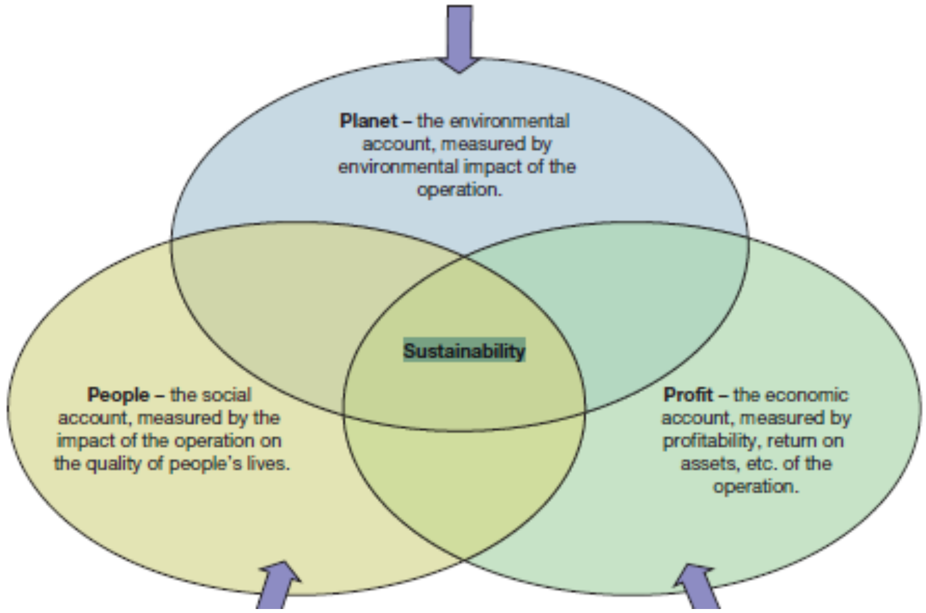

Figure 1 Triple Bottom Line (TBL) framework. Adapted from Slack et al. (2013)

1.2. Sustainability in BPM

According to Drake et al. (2013), operations management (OM) represents a key element in sustainability. At the micro-level, firms' operational decisions determine the production and distribution technologies and system design that they employ. These in turn determine how efficiently (and which) materials and energy are consumed as well as the type and intensity of waste injected into ecosystems, which aggregate to determine global source and sink consumption rates and, ultimately, the sustainability of an ecosystem with respect to human activity. Sustainable OM is therefore a potential important role to play in contributing to solutions for the sustainability challenges that are currently faced.

According to Panagacos (2012), Business Process Management (BPM) is a field in operations management that focuses on improving corporate performance by managing and optimizing a company's business processes. BPM has evolved as a holistic management practice for managing and transforming organisational operations (Hammer, 2010). The methodology provides adequate techniques for the design, execution, control and analysis of business processes to improve value creation within single organisations and inter-organisational value networks (van der Aalst, ter Hofstede & Weske, 2003).

Some researchers such as Recker et al. (2012) and Gallotta et al. (2016) have already investigated the potential of the use of BPM in sustainability. According to Recker et al. (2012), the dedication of BPM approaches to eliminate waste indicates its potential for making processes more sustainable. It is also possible to extend and adopt Business Process Management methods to allow organizations to manage and improve the organizational processes in light of environmental, social and economic considerations.

2. Methodology

This section presents a methodology to help companies to implement sustainability initiatives. The methodology comprises of four steps: (1) Analyse; (2) Design; (3) Implement; and (4) Monitoring & Control. These steps are part of the framework to implement sustainability initiatives in the business processes (Gallotta el al., 2016). Steps (1) to (4) are carried out by relying on certain methodological steps that have been discussed elsewhere. Figure 2 represents the framework.

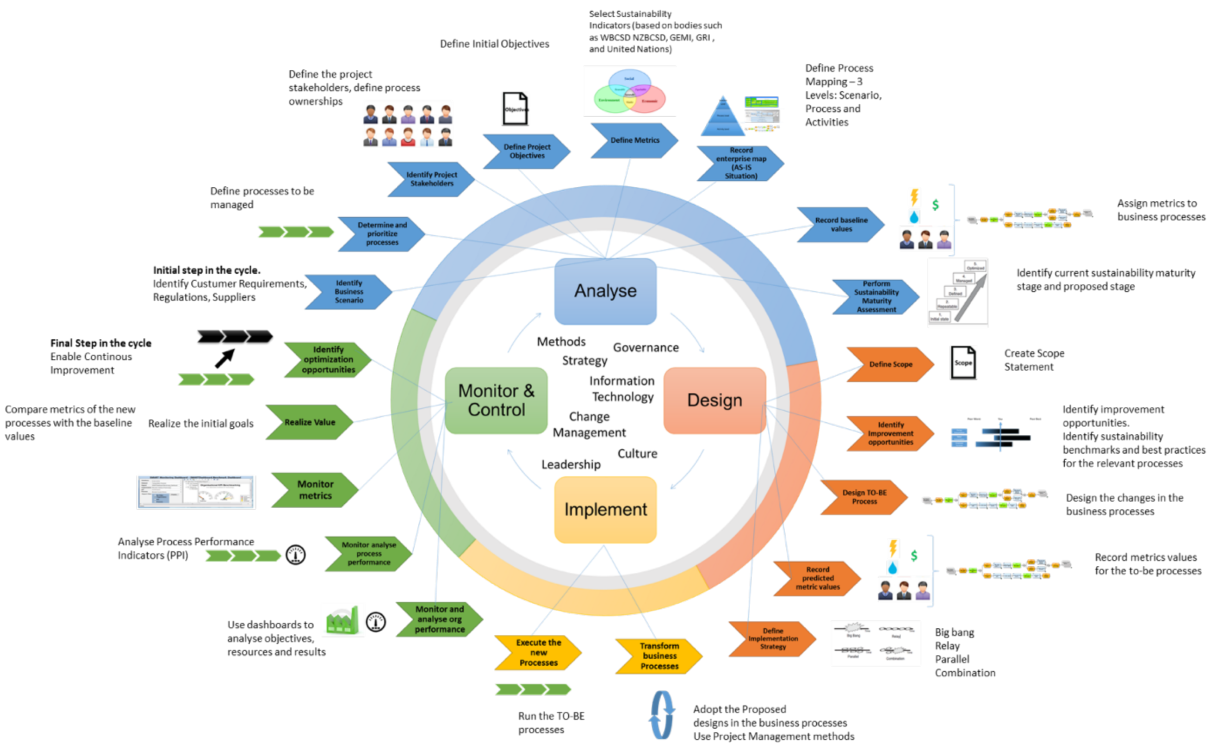

Figure 2 Framework to implement sustainability initiatives in the business processes. Source: Gallotta el al. (2016)

3. The case study

Company A is a biomass power generation company. The organisation defines itself as an energy innovation company and uses torrefaction to transform wood into bio-char. The main focus of the company is to develop sustainable energy technologies, implement technology into renewable energy production plants, develop projects, license technology to third parties and develop state-of-the-art torrefaction technology; this commitment to sustainability was the main reason to select Company A for this study.

3.1. Analyse

The 'Analyse' phase aims to assess and evaluate all the relevant aspects related to the implementation of sustainability in the business processes. The main element in this phase is to define the project metrics which were categorized into sustainability metrics and process metrics.

The sustainability metrics were divided into the triple bottom line dimensions (social, economic and environmental). According to the Global Reporting Initiative (2015), economic performance can be measured in terms of direct economic value generated which includes financial implications and other risks and opportunities for the organization's activities due to climate change, coverage of the organization's defined benefit plan obligations and significant financial assistance received from government. For this project, the most adherent would be the direct economic value generated in form of operating costs.

The materials performance can be measured in terms of materials used and recycled by weight, volume or percentage. The quantity of materials consumed is considered to be more relevant to the study.

According to Global Reporting Initiative (2015), water performance can be measured in terms of total water withdrawal by source; water sources significantly affected by withdrawal of water; percentage and total volume of water recycled and reused. The percentage of water reused by the process was selected for this study.

GRI (2015) states that the Emissions, Effluents, and Waste performance can be measured in terms of total direct and indirect greenhouse gas emissions by weight; other relevant indirect greenhouse gas emissions by weight; initiatives to reduce greenhouse gas emissions and reductions achieved; emissions of ozone-depleting substances by weight; NO, SO, and other significant air emissions by type and weight; total water discharge by quality and destination; total weight of waste by type and disposal method; total number and volume of significant spills; weight of transported, imported, exported, or treated waste deemed hazardous; identity, size, protected status, and biodiversity value of water bodies and related habitats significantly affected by the reporting organization's discharges of water. For this research, the most relevant indicator was the total weight of waste by type (tar) and disposal method.
According to the organisation, the Occupational Health and Safety performance can be measured in terms of injury ate (IR); occupational disease rate (ODR); lost day rate (LDR); and absentee rate (AR). For this study, it was only assessed the IR. More than that, it will be also assessed the health and safety related trainings per employee (and furthermore relate them with the IR).
In terms of process, Slack (2013) defines that the process performance can be measured in terms of cost, time and quality. For this study, it was considered the production cost per ton (cost); cycle time per ton; and percentage of products (biochar pelletized) under specification (quality). Therefore, Figure 3 summarizes the metrics to be measured in the project.

Economic	Environmental	Social	Process Performance
Direct economic value generated	Materials	Occupational health and safety	Cost
Operating Costs	Materials used by weight or volume	Injury rate (IR)	Production Cost per ton (Pct)
	Water	Training	Time
	Percentage and total volume of water reused	Health and safety trainings per employee	Cycle time per ton (Ct)
	Emissions, effluents, and waste		Quality
	Total weight of waste by type and disposal method - tar		Percentage of products (pellet) under specification (Pus)

Figure 3 Project Metrics – summary

Figure 4 and Figure 5 represent the calculation method for the defined metrics.

	Sustainability performance			
				Calculation method
Dimensions	Economic	Direct economic value generated	Operating Costs	Obtained from Company A reports
	Environmental	Materials	Materials used by weight or volume	Obtained from Company A reports
		Water	Percentage and total volume of water reused	Mass balance between: capacity of the water tower, amount of water evaporated, amount of water drained, water obtained from the rain and water obtained from the mains
		Emissions, effluents, and waste	Total weight of waste by type and disposal method - tar	Obtained from Company A reports
	Social	Occupational health and safety	Injury rate (IR)	$IR = \frac{Total\ \#\ of\ injuries}{Total\ hours\ worked} x\ 200{,}000$
			Occupational diseases rate (ODR)	$ODR = \frac{Total\ \#\ of\ Occupational\ disease\ cases}{Total\ hours\ worked} x\ 200{,}000$
			Lost day rate (LDR)	$LDR = \frac{Total\ \#\ of\ lost\ days}{Total\ hours\ worked} x\ 200{,}000$
			Absentee rate (AR)	$AR = \frac{Total\ \#\ of\ missed\ (absentee) days\ over\ the\ period}{Total\ \#\ of\ workforce\ days\ worked\ for\ same\ period} x\ 200{,}000$

Figure 4 Sustainability Performance calculation methods

	Process performance	
		Calculation method
Cost	Production Cost per ton (Pct)	$Pct = \frac{Cost\ of\ production}{Amount\ of\ bio\ coal\ produced}$
Time	Cycle time per ton (Ct)	$Ct = \frac{Amount\ of\ bio\ coal\ produced(batch)}{time}$
Quality	Percentage of products (pellet) under specification (Pus)	$Pus = \frac{Amount\ of\ bio\ coal\ products\ under\ specification}{Amount\ of\ bio\ coal\ produced}$

Figure 5 Process Performance calculation methods

3.2. Design

The 'Design' phase aims to propose the changes in the business processes by designing the expected situation. The main objective of the study is to provide a solution for the tar generated through the conversion of biomass to energy. The initial idea was to reutilize it in a different part of the process as a moisture source to reduce disposal costs.

Other objectives of the study are to raise the percentage of water reused in the process, relate the injury rates with the specific process in order to control them in a better way and relate the injury rates with the health and safety trainings. Six possible solutions were identified to solve the problem: 1) Disposal down the drain; 2) Sell as raw material; 3) Filtration using activated carbon or other chemicals; 4) Incineration (Oxidizer) – Option 1 with pyrolysis condensate in liquid form; 5) Incineration (Oxidizer) – Option 2 with pyrolysis condensate in vapour form; and 6) Inject directly into stack.

When considering plant operational injury rates, it was identified that in 2015 most of the accidents took place in the control room and reactor (28.57% each). In 2016, the majority of the accidents occurred on the pellet line (41.66%). This might indicate that additional training is required on the safety aspects of the pellet line. Another objective in terms of trainings would be to have 100% of the staff capacitated in the 'High Importance Training Need'.

In order to identify the best solution for the tar treatment a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis was made and it was identified that the best solution would be selling the tar in form of wood vinegar. However, it is a solution that takes time to be deployed. Therefore, it was established that it would be the long-term solution. Whereas, the short time solution would be disposing it down the drain after the chemical treatment.

3.3. Implement

The 'Implement' phase is when the project is in fact implemented, when the technical execution happens. For the short-term solution, for disposal down the drain, the local water company was contacted to analyse the sample. Currently the company is working on ways to reduce the phenol concentration, in order to meet the legal requirements. For the long-term solution, it was identified that tar is raw material to several products, such as fertilizers, pesticides, shampoos, dermatological products, cleaning products, among others in form of wood vinegar. According to the Food and Fertilizer Technology Center for the Asian and Pacific Region (2005), wood vinegar (tar) is a by-product from charcoal production that improves soil quality, eliminates pests and controls plant growth, but is slightly toxic to fish and very toxic to plants if too much is applied. It accelerates the growth of roots, stems, tubers, leaves, flowers, and fruit. In certain cases, it may hold back plant growth if the wood vinegar is applied at different volumes.

Last year, Company A spent £18,050 to dispose the tar (95 IBCS, using services of a third-party company). With the full production, the organization will generate, theoretically, 8301 m^3 of tar, consisting a cost of £1,577,190 per year (if disposed in the current way).

It was found that one supplier of wood vinegar charges U$2,250 (approximately £1,733) for 1 m^3. Considering that last year 95 m^3 of tar liquid was produced, it could theoretically represent a possible revenue stream of £156,403.25. Considering the values of full production (183.64 m^3 of tar), this could represent a revenue of £14,385,633 per annum (without considering the costs of transportation or market volume. The market study is likely to conclude that the market demand is in small volume, therefore the actual value of the tar sales will be much smaller in commercial practice). Figure 6 represents the theoretical tar revenue analysis.

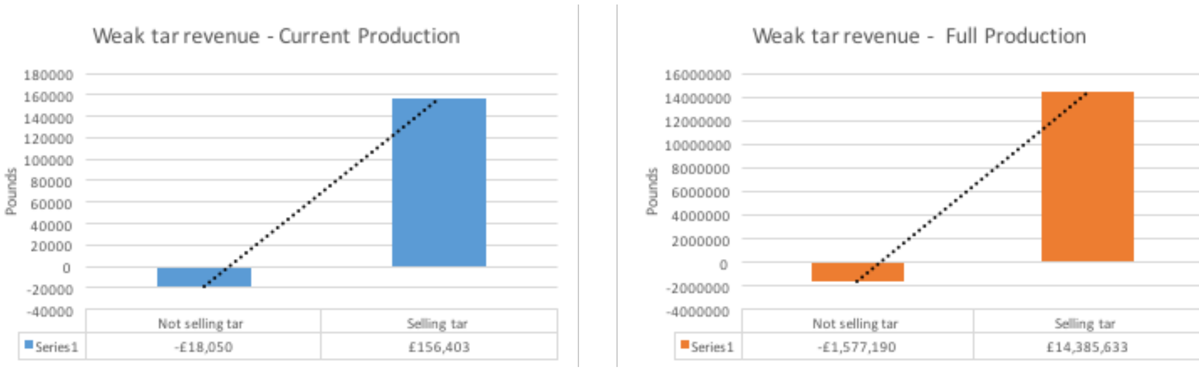

Figure 6 Tar profitability analysis

Consequently, this would also require a redesign of the process; the process to transform tar into wood vinegar (meeting the wood vinegar standards); as well as the connection between the channels of communication from Company A and the buying organisations (added to the costs to create the network, costs to transport the wood vinegar, among others).

3.4. Monitor & Control

The 'Monitor & Control' phase contains the steps that are necessary to evaluate the status of the implementation. According to Sanchez (2014), projects are monitored in order to track their development (updating costs and benefit estimates to detect deviations) and re-prioritize them when strategic goals (or their target values) change, new initiatives appear, or projects are finished. Figure 7 represents the Sustainability Performance summary; Figure 8 represents the Process Performance Summary.

	Sustainability performance				
				AS-IS situation	TO-BE situation
Dimensions	Economic	Direct economic value generated	Operating Costs	Fixed costs: 904,000.4 euros/year Variable costs: 7,152,000 euros/year * based on 2 production lines	
	Environmental	Materials	Materials used by weight or volume	44 tons of wood 2 tons of binders 500 Kg of lubricants	
		Water	Percentage and total volume of water reused	66.57%	
		Emissions, effluents, and waste	Total weight of waste by type and disposal method - tar	95 m3 of weak tar	8,301 m3 weak tar (5,646 m3 to be used as binders)
	Social	Occupational health and safety	Injury rate (IR)	70 in 2015 130 in 2016	
			Health and safety trainings per employee	Emergency First Aid at work 70.59% Risk Assessment 100.00% Work at height 82.35% Use of firefighting equipment 94.12%	100% 100% 100% 100%

Figure 7 Sustainability Performance - Summary

	Process performance		
		AS-IS situation	TO-BE situation
Cost	Production Cost per ton (Pct)	97,409.1 euros / ton	
Time	Cycle time per ton (Ct)	0.25 tons / h	
Quality	Percentage of products (pellet) under specification (Pus)	6%	

Figure 8 Process Performance – Summary

In addition, regular measurements for the proposed metrics and the use of statistical process control charts (SPC) were outline or determined. Figure 9 represents a SPC. The objective of this chart is to evaluate the variation of the specific metric (e.g. tar generated) at different dates.

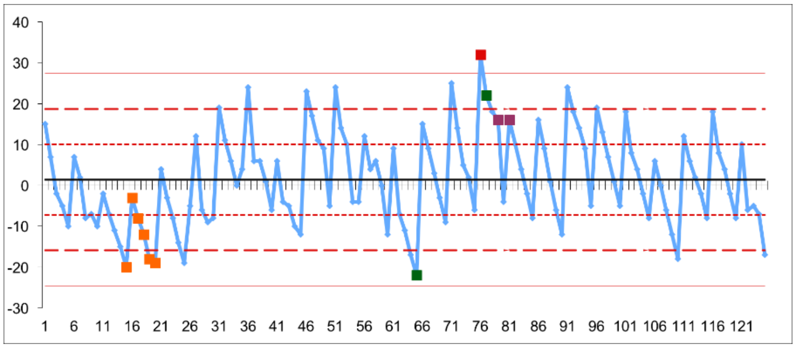

Figure 9 Example of a Statistical Process Control (SPC) chart

4. Results and Limitations

This paper provided a study performed in a biomass power generation company that was producing an excess of tar. In order to provide a solution to the tar generated, the Business Process Management (BPM) approach was selected to implement sustainability business processes within the organisation. The study defined two solutions for the issue, 1) short-term – disposing down the drain and 2) long-term – selling the tar as wood vinegar. Currently the company is organising the development of both short-term and long-term solution. For the meantime, the company is studying methods to reduce the phenols amount of the residue in order to comply to the legal standards. For the long-term, the company is developing a market study in order to identify potential customers, competitors, and requirements for the wood vinegar. Therefore, it is possible to conclude that the study provided tools for a better management of the processes, which will improve the sustainability status of the organisation.

The main limitation of this paper is the estimated results calculated at the present time before the study has reached completion, thus a subsequent paper aims to outline the actual final results and compare to the current estimations. Future research also aims to consider aspects related CO_2 and its footprint on the supply chain.

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6. Biography

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Bruno Gallotta is a PhD candidate in Sustainability and Business Processes at the University of Derby, Derby United Kingdom. He earned BSc in Science and Technology from Universidade Federal do ABC, Brazil, BSc in Management Engineering from Universidade Federal do ABC, Brazil, and Masters in Research from University of Derby, United Kingdom. He has published conference papers. Mr. Bruno has been a Business Consultant since 2010, with experience in Knowledge Management (KM), Process Design, Internet of Things (IoT), IT Corporate Sustainability and Business Process management (BPM). Participation in projects of different lines of business, such as Mining, Oil&Gas, Biomass and Manufacturing. His research interests include sustainability, Business Process management, manufacturing, Project Management, optimization, and Information Technology. Currently developing a research project regarding sustainability and BPM.

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Vidrene Kolelas is a native French speaker who graduated from Aston University with a MEng degree in Chemical Engineering. She further studied MSc Innovative Engineering Solutions at the University of Derby and completed an internship at a Power Generation plant as part of her course. The projects in which Vidrene was involved required her to work with wood tar to find out its properties and applications. Her career goal is to specialise in this area still under development to gain an in-depth knowledge of it and further develop her technical skills to help her achieve the level of competency required to become a Chartered Engineer.

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Jose Arturo Garza-Reyes is a reader in Operations Management and Business Excellence at the Centre for Supply Chain Improvement, Derby Business School, the University of Derby, UK. He has published a number of articles in leading international journals and conferences, including *International Journal of Production Research*, *Production, Planning & Control, International Journal of Production Economics*, *Journal of Cleaner Production*, *Robotics and Computer Integrated Manufacturing*, *Journal of Manufacturing Technology Management*, *International Journal of Quality and Reliability Management*, *TQM & Business Excellence*, among others. Garza-Reyes has also written two books in the areas of quality management systems and manufacturing performance measurement systems. He has participated as a guest editor for special issues in the *Supply Chain Management: An International Journal*, *Production Planning & Control*, *International Journal of Lean Six Sigma*, *International Journal of Lean Enterprise Research*, *International Journal of Engineering Management and Economics*, and *International Journal of Engineering and Technology Innovation*. Jose Arturo is co-founder and current Editor of the *International Journal of Supply Chain and Operations Resilience* (Inderscience). He is currently serving in the editorial board of several international journals as well as a member of the scientific and organising committees of several international conferences. His research interests include general aspects of operations and manufacturing management, operations and quality improvement and performance measurement.

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