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Research article

A decision support system for environmentally-sustainable strategies for the Mauritian Textile and apparel industry using system dynamics: The materials and land perspectives

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ABSTRACT

As anywhere in the world, Mauritius has seen the depletion of its natural resources, mainly as a result of the effects of global warming. Industries need to recognize this and rethink on the way products are manufactured so as to minimize the negative impact of their businesses on the environment, the workforce and the surroundings. The main objective of this research is to investigate what support systems the Mauritian Textile & Apparel industry requires to embark on a sustainable manufacturing journey. The primary focus of the research is from the perspectives of the use of materials and land availability. This present work is not about "Greenwash", it is about analyzing the full range of economic, environmental and social benefits to support the transitions to sustainable business models over time. Development of methods that can support academics, researchers and industry practitioners within the textile & apparel industry to integrate sustainable manufacturing practices into their day-to-day practices. In a nutshell, this research provides a cut-and-dried and standardized approach for the stakeholders of the textile and apparel industry to shift to more sustainable practices by reshaping their resource flows. This study confirms the dynamic behavior of the textile industry and reveals that if the appropriate strategies and decisions are made, there is still hope for the survival of the industry in the future.

1. Introduction

The transition from an established agricultural to a manufacturing, tourism and financial services based economy has been quite a big achievement for Mauritius. The country is now more focused to move in the hierarchy from being a middle to a high income status economy. The biggest challenge that Mauritius needs to work upon is to enrich its competitiveness to sustainably shift a gear and move up the value chain. However, this move is being hampered by the flaws in infrastructure and the education system which are in return impacting on the quality of its human capital, productivity and innovation capacity. Industries are more focused on economic benefits than anything else. In fact, they consume large amounts of non-renewable resources and creates waste and pollution (Cassetari et al., 2017). Being small and remoted does not help either. On the contrary, this increases the country's vulnerability to economic and social shocks, but also to environmental deterioration.

The manufacturing sector is constantly facing the challenge to make sure that no harm is done to the environment and the ecosystem. The objectives were to meet the environmental sustainability targets of the Millennium Development Goals [1], and reduce the ecological footprint to be in the upper quartile of performance of similar income nations, by 2020. It's still remained to be

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established how far this goal has been achieved. However, it's not for lack of trying from all stakeholders of the sector. The commitment by the government towards sustainability was confirmed in 2017 whereby the country signed and embarked on the pursuit of Agenda 2030 and the Sustainable Development Goals (SDGs). Amid the main consequences is that there has been an increase in the global average surface temperature and the impact has been mostly felt in the Polar Regions where snow melting has occurred and a resulting widespread retreat in the mountain glaciers. This is even more important for Mauritius because if the sea-level is expected to rise, this can present significant risks and may even threaten the island's existence in the long term. Human activities largely contribute to global warming and this will continue. It has become very urgent to start thinking about ways and means to alleviate the pressure of dealing with climate change before it becomes beyond our control.

It can be argued that the Government of Mauritius has been doing a laudable effort in moving towards sustainability. This confirms its commitment to turn the country in a sustainable island. In its programme for the year 2015–2019 which was released in January 2015, sustainability and eco-friendly development is ranked high in its agenda and hence confirmed its desire to continue with the good work that had already started some years back. The result of which is to pave the way towards a cleaner and safer Mauritius. It is imperative that most, if not all, important sectors of the Mauritian economy should move towards SD and sustainability practices in order to meet the future challenges of climate change, energy challenges among others.

This study can prove to be very decisive for the textile industry due to its unequivocal nature. The main reasons are:

- All materials are imported;
- The industry is a high energy user and Mauritius has no oil or coal resources;
- There is little or no recycling of textiles in Mauritius;
- It is a potential source of significant environmental impact;
- The sector is a significant source of employment and contributor to the economy;
- It faces many challenges from global competition;
- There is an increasing energy and raw material costs and is fashion driven therefore volatile and Mauritius is a long way from key markets.

Therefore, in a way the challenges facing Mauritius in terms of SD with limited/minimal natural resources are a good reflection of the challenges facing the global economy and the challenges facing the textile industry in Mauritius are complex and include every aspect of SD.

The key questions to which immediate/urgent answers that arose are:

- What are the pre requisites required to go towards Sustainable Manufacturing (SM) in the industry?
- Where does the Manufacturing and the Textile and Apparel Industry position itself in the journey to sustainability through sustainable manufacturing?
- What would be the best SM strategies for the textile and apparel industry in the future to sustain its economic activities.?

This research focusses more in finding appropriate actions/replies to the materials and land elements linked to the textile and apparel industry in Mauritius. The main objective is to come up with a proof the concept by building a prototype decision support system for the textile and apparel industry. The artifact developed in this research work focuses on the materials and land perspectives and will assist in future strategic decision making for environmentally sustainable operations within the industry. This research work attempts in finding the most pragmatic answers to the key research questions.

Research gaps and contribution to the body of knowledge.

The contributions to knowledge of this piece of research work are:

- The development of methods that can provide support to academics, researchers and industry practitioners working within the textile and apparel industry to integrate SM practices into their day to day operations.
- The gap between "what is the current practice of the industry" and "what should be ideally done to have a 'greener' industry".
- The development of a 'Decision Support System' which is a novel tool that can be used by stakeholders in the textile and apparel industry, locally and worldwide, to test the possibility and validity of adopting SM practices. This can also assist in the decision making process and development of policies and legislations with regards to sustainability in the industry.
- The provision of the basis for textile companies to embark on a circular economy approach. The concepts of value cycles linking markets, design, manufacture and logistics with technology, materials, business processes, legislations, social and cultural, economic and environmental impact was used to develop a holistic and multidisciplinary approach for the textile and apparel industry.
- Another important contribution to the body of knowledge is the development of the basic principles of developing a holistic model of the T&A industry. This is a step ahead from the general modelling, whereby system dynamics is the principle on which the model is built.
- This piece of research work will help researchers and industry practitioners to further enhance their understanding on a number of primary considerations in the application of circular economy within the Mauritian textile and apparel industry.

2. Literature review

In this section, a quick literature review has been carried out to be able to disclose the links between sustainable manufacturing and system dynamics. This will be used in the development of decision support models for the choice of materials in the textile and apparel industry.

2.1. Definition of SM

In a comprehensive review of the literature on manufacturing strategy, Dangayach and Deshmukh [2] identified 'green' manufacturing as one of the most important research themes of the future. However, even after several years of research in SM, a prevailing definition among scholars still does not exist. Furthermore, many authors argue that there is no common understanding of what SM is [3-5] whom all highlighted the problem of numerous definitions. In addition, [6] state that there is no generally accepted or universal definition of SM, and there are many inadequate attempts. . The same authors posit that these attempts failed short mainly because scholars fail to stress the correlation between products, processes and systems, which are the intrinsic elements of manufacturing. It was also mentioned that only a few studies dealt with environmental issues in manufacturing. Since then, ample research work has been done in this field with loads of publications, reports from global conferences and meetings, etc. But the big question is how far all these have been successful to date. From a pessimistic point of view, it can be said that the world's natural resources is still depleting and the predictions by Meadows et al. (1972) in their book "Limits to Growth' may turn out to be true. But from an optimistic point of view, it can be seen from the literature, that much effort is being done by all the stakeholders in the industry to ensure that future generations still take benefit from the natural resources of the world. However, there is still some difference in views between academics and researchers. In a survey of environmental management in the UK, Dahlman et al. [7] concluded that systematic and strategic practices related to the management of environmental issues in business are rather rare. Indeed, further efforts have been done by both researchers and academics and practitioners since then, but there is still room for more to do and to come. Mauritius, being no exception from the rest of the world, has recognised that environmental sustainability is fast becoming a major business performance criterion.

Some of the most common definitions of SM in literature are given below (see Table 1):

2.2. The need for sustainable manufacturing (SM)

Jovane et al. [15] acknowledge that manufacturing is the heart of any industrialized society and that manufacturing generates, directly and through services, wealth and jobs. This was later confirmed by Hermann et al. [16] who observed that manufacturing is one of the main component for the well-being of nations and the origin provider of innovation and evolution. In other words, manufacturing is at the core of the industrial economy and encompasses all different types of services related to the manufacturing chain. Malek and Desai [12] opined that the traditional manufacturing methods focus on producing products without considering their negative impacts on the environment. To perpetuate the operations of an organization, it must be able to meet the needs of the present and avoid compromising the rights and resources of future generations [13].

Liabilities with regards to the environment related activities in the industry have become an important concern and have for long

Table 1
Selected definitions of SM from Literature.

Author(s)	Sustainable Manufacturing Connotations
Garetti and Taish [8]	SM involves making the best out of natural resources for developing products and services. This encompasses the use of new technology, regulations and systematic social goals. In a sense, providing a better life quality and at the same time protecting the environment.
OECD [9]	SM is all about maximizing new opportunities arsing from process and product improvements while minimizing the various business risks inherent in the manufacturing process.
Intelligent Manufacturing Systems (2011)	The purpose of SM is to mitigate the impacts on the environment by reducing the use of available resources in the manufacturing sector. This is achieved by the creation of new methods, practices and technologies.
International Trade Administration, (2013); Mani et al. (2014)	SM is described as the advent of goods by using environmentally friendly processes that take into consideration the preservation of energy and natural resources and be profitable at the same time.
Geyer [10]	" SM refers back to the vision of manufacturing systems in which manufacturing and consumption help people quality of life by using environmentally and economically sound methods. [K]knowledge and technology, funds, resources and desires are harnessed and governed so that people can have a better life without compromising the use of further materials and energy.
Roberts and Ball [11]	SM is the techniques, rules and methods an organization makes use of to create goods that use practices that minimize adverse environmental impacts, preserve energy and natural resources.
Jawahir and Bradley [6]	Sustainable manufacturing embraces new approaches to manufacturing goods using sustainable technologies, as long as product design, production, supply chain design and management, and logistics are well defined and understood.
U.S. Environmental Protection Agency (2017)	The advent of products manufactured using economically viable processes that conserve the energy and natural resources while reducing negative environmental impact. SM also cares about its employees and community at large.
Malek and Desai [12]	Sustainable Manufacturing is an initiative which integrates both the environmental and economical facets of the business.
Yip and To [13]	SM is critical for the forthcoming manufacturing and its development is metamorphic.
Alayon et al. [14]	Sustainable manufacturing is discussed from the context of the triple bottom line, which considers the three dimensions of sustainability with the manufacturing business sector: environmental. Social and economic.

been a great challenge for our society (Carson, 1962 [17,18]; Meadows and Club of Rome, 1974). Human beings are constantly pursuing higher life quality and this has led manufacturing firms to come upon a compelling challenge of producing more products whilst using fewer resources as well as emitting less pollution ales wastetes [19]. This is putting much pressure on manufacturing companies. The situation for these companies is expected to be more and more complex than it used to be some years back, since apart from pressure from customers, they also have to face much stress from governmental institutions to pact with the issue of environmental degradation. More and more challenges are emanating from customer demand, necessity for eco-friendly production reducing environmental aspects, including social aspects importance as well [16].

Ghahramani and Khalkhali [20] observed that more and more manufacturing firms are being forced to reconsider their approach in conducting business and operations since the emergence of the sustainability concept. Conventional manufacturing methods have caused many problems for humans and the environment, including global warming, depletion of non-renewable resources, dangerous diseases, among others (Ghandeharium et al., 2016; [21]). Companies nowadays have to rethink the strategies adopted with respect to their system of manufacturing, since natural resources, energy and materials are becoming less and less abundant. The manufacturing sector has caused a lot of harm and just by looking around, any casual observer can conclude how harmful has the sector been to the environment. The most obvious ones are global warming and greenhouse gas emission, air contamination, water and soil pollution, significant use of non-renewable resources, and bad wastes management [22].

Hu et al. (2010) recommended that enhancing research in manufacturing will help re-boosting the US Manufacturing sector. Europe, on the other side, has targeted the year 2020 to reduce GHG, to increase the use of renewable energy and improve the energy efficiency. In the same line, the project 'IMS2020': Supporting Global Research for IMS202 Vision, was launched by the intelligent manufacturing systems (IMS) programme and funded by the Industrial Technologies Directorate in the DG Research & Innovation of the European Commission. Five priority areas were identified in the technological and strategic roadmap for future (2020), which were:

1. Shifting to SM
2. A manufacturing sector with less energy wastage
3. State of the art technologies
4. Ethics
5. Education

As concluded by Hermann (2014), adapting to new challenges and trends is paramount for manufacturing to remain competitive, and the last two centuries have brought about several changes to this sector's archetype. More and more challenges from customer demand, the call for eco-friendly production reducing environmental aspects, including social aspects, importance as well. The survival of the manufacturing organisations depends on their credentials and speed of response to the changes in the external environment [23]. Companies of the future need to address all the three dimensions of sustainability, moving from today's rather economical focus towards ecological and social strategies. In other words, SM MUST be integrated within the whole supply chain when considering physical products, from designing the system till the promotion and sales phase.

2.3. System dynamics

By looking at all the papers published with regards to systems thinking and SM, and SSM, in particular, system dynamics appeared to offer a possible way forward for achieving the aims of this research work. The use of System Dynamics proved to be convenient as it would be easier to understand the complicated interactions of the different factors of the Mauritian Textile and Apparel industry, even more, so the latter being a complex system. Forrester (1961) introduced System Dynamics in the early 1960s as a modelling and simulation methodology for long-term decision-making in dynamic industrial management problems and also been applied this concept to a variety of business policy and strategic problems (Barlas, 2002; [24]). All systems thinking approaches have to do with simplifying reality so that it can be dealt more effectively. In fact, the field of SD celebrated the 60th anniversary of its founder, the late Jay Forrester. This provided an opportunity and platform for researchers to reflect and celebrate their many achievements in this field. These include extending the SD Toolkit to provide a more robust method for capturing network dynamics [25], the interaction of dynamics on multiple scales [26], and experiments on group modelling, methodical advances, including a systematic study [27] as well as the insights from his integration of system dynamics and operations research [28], along with the applications in medicine [29] among others. So it can be seen that SD has gone a long way since its inception by Jay Forrester in the 1960s. System dynamics offers an approach in which the model resembles reality structurally, that it can be reviewed for usefulness and consistency. Furthermore, it offers the possibility for dicarifications of that simplification through simulation, so different scenarios can be tested as well. The key differentiators of System Dynamics are that:

- The modeled and the actual world structures have associated features information feedback seems to be the core element of SD.
- SD Models can accommodate both quantitative and qualitative elements.

Multiple axioms can be simulated by using system dynamics modelling.

Cosnz and Noto (2016) posit that the use of the SD methodology has till now established to be a very pragmatic approach to support both the comprehension and learning processes of complex systems and phenomena. From the same study, it was deduced that SD can be a reliable tool in captivating the interests of internal and external stakeholders. This methodology has been applied to different field of research. This research looks at one of the gaps that were found in the literature review whereby System Dynamics can be used in providing insights into the complex textile and apparel industry. System Dynamics was most particularly used in looking at the underlying causal relationships within the industry. Another important aspect of System Dynamics most relevant to this piece of research is the ability to provide feedback. Conceptually, the notion of feedback is central to the system dynamics approach. Gestating the structure of the textile and apparel industry as a complex system using informational feedback loops and cyclic causality. Allegedly, a feedback loop is when information from an action flows through the systems and eventually finds its way back in some or another to influence future actions and either reinforce (positive) or counteract (negative). Balancing loops can be variously characterised as a process of goal pursuit, balance, or stabilization. Combining reinforcement and balancing of circular causal feedback processes can generate all kinds of dynamic patterns.

System dynamics is a common approach used to build up learning about complex systems. For system dynamics, the world is a comlex system where everything is connected to everything. The same principle applies to the Mauritian Textile and Apparel industry. It is therefore important to understand the system before changing any high leverage point in system, identify the linkages, feedbacks and time lags. This will help anticipating the consequences (intended or unintended) of the modifications done. The System Dynamics methodology used in this study was a modelling and simulation technique specifically designed for long-term and continuous dynamic management problems, proposed by Barlas (2002). It focuses on understanding how physical processes, information flows, and management/strategic policies interact to create the dynamics of the variables of interest. In fact, it can be said that the set of the relationships between the various components define the structure of the system. It is the latter that works over time that creates the dynamic behavior patterns. The current real life description of the process being modeled is mandatory. The main purpose of using system dynamics here is to understand how and why problem dynamics are generated and to look for guidelines/strategies to further improve system performance. The policies refer to medium to long-term macro-level decision used by the important stakeholders of the textile and apparel industry in Mauritius. The interrelationships between the four main domains identified in this research, i. e environmental, manufacturing, economic and social, are discussed at a later stage of the research work. The influence and impact they have on each other, with significant time-lags, and with feedback loops and the outcomes produced are of utmost importance for this research work. A better comprehension of these 'dynamics' within and among systems is an important part of taking effective integrated strategic decisions.

System dynamics is particularly different from other traditional simulation/modelling techniques, such as discrete event simulation. A major modelling problem is the point-to-point matching between model behavior and actual behavior. Comparatively, in System Dynamics modelling, it is important to generate the main 'dynamic patterns' of interest. In fact, system dynamics provides a more logical and accurate problem-solving framework which aim at finding the purpose of problems, extorting views and comments from participants about the root causes. System Dynamics has been used plenty of times for studying environmental systems as provided by Ford (1999). SD models can be used to capture disequilibrium [30]. The latter posits that models are more sensitive to uncertain outcomes, but both model behavior and policy recommendations are typically much more sensitive to the width of model boundaries than to uncertainty of parametric assumptions. All in all, SD can impel the change process by essentially watching over cooperation and ownership. By embracing SD in any organization's change process, the management team uses a more objective approach and accepts that other people take the lead in implementing the proposed changes. Instead of personifying the change process, management becomes a servant of the change process. This separations not only gives a bird's eye view of the process and the active external forces, but also the lead time to take necessary corrective actions thrown by the SD system.

2.4. Sustainable manufacturing in the textile and apparel industry

Until recently, the development of the textile and apparel industry focused on technology and cost aspects. The priority of this sector is to have an improved and more efficient production and keeping the price down, as far as possible. Textile industry has delocalized and moved countries, with lower costs implications, the environmental impacts has also followed. Due to population growth and development in economic context, the demand in textile products is expected to increase (Sandin and Peters, 2018). The remaining 37% is dominated by cotton, which has a share of 24% of the textile fibers. The latter is known to be a thirsty plant and requires an intensive use of pesticide to grow (FAAO-ICAC, 2015). For most categories of environmental impacts, later stages in the textile production process give rise to even larger impacts (Roos et al., 2015). Processes in the textile industry are major sources of noxious emissions (Roos et al., 2015).

The clothing industry is based on extremely fast fashion cycles and unsustainable consumer desires. Declining quality, short-term use, frequent clothing changes, and increased textile waste are therefore a burden on the environment. In landfills, methane is generated from this waste to the atmosphere and due to toxic substances have polluted the groundwater [31]. Designers, manufacturers and retailers pay less attention to other aspects of their offer. It is therefore important to anticipate how to meet the demands of the textile industry in a more sustainable way.

At present, the focal points for many businesses are more associated to sales and production aggregates only. Therefore, more sustainable consumption is seen only as a major reason for lower production volumes and manufacturing profitability, and not as an opportunity for a new breed of green companies, [32]. As Perrels [33] points out, sustainable development issues are changing not only in production systems, but also in consumption patterns. Models are more focused on product design, end of-life management, technology, and life cycle management as well as supply chain management.

The nature of the industry itself is such that it is so dynamic, it is governed by its consumption pattern. Welters [34], in her work 'The Fashion of Sustainability' presents sustainability as it is understood today, represents a juncture with fashion since 1600. Welters stresses that sustainability is not a new concept in fashion history, but part of its repertoire. Basically, Fletcher [31] argued that the way we wear clothes provides a reflection and of people's perception and vision of their surroundings. Clothing is the material thing that gives fashion a contextual vision in society (Cataldi et al., 2010).

3. Methodology

The research problem is somewhat not conventional and required a more modern and different approach. It did not line up with the classical research methodologies as described by Robson [35]. In order to meet the aims and objectives of this research work, the systems modelling approach (SSM) was considered. Based on the literature, SSM was found to meet the objectives of the research work and was therefore selected. SSM was developed by Peter Checkland to address soft problem-solving. The main use of SSM is the analysis of complex situations ('soft problems') where there are different views on how the problem is defined. Checkland [36] describes soft problems as follows: This is a classic situation where there was both a problem and an opportunity. SSM seemed best suited to first structure the problem domain and then propose a blueprint for modelling the textile and apparel industry. Then this will be used as an assessment tool to test different 'what if' scenarios. However, the models would need to be validated first, before it could be used. This was done through the various focus group discussions and mediations between the experts from academia and industry.

Zhang et al. [37] concluded that System dynamics provides a suitable framework for modelling manufacturing systems for sustainability assessment. He also notes that the main perks of system dynamics is that it enables decision makers to understand the system by identifying relationships between factors, to simulate how the system is currently working, and to explore opportunities for improvement. This includes structured models to enable and help decision makers make predictions. Most importantly, it provides engineers and managers with an approach that applies systems thinking to solve SM problems holistically. The proposed methodology for modelling and verification of the Textile and Apparel industry is shown in Fig. 1 below:

The textile and apparel industry in Mauritius, when viewed holistically, can be categorized as a complex system. In fact, there are no models of the industry readily available whereby experimentation can be done. Hence the entire system needs to be designed and developed from scratch. An integrated methodology was used for conducting this research work. This includes theory construction, system development, experiments and research which is more appropriate to meet the objectives set for this work. Even though Systems development methodology is more likely to be found in the engineering and computer science fields, rather than management, this methodology was deemed to be a valid research methodology for this work. This methodology is not a standalone one and is complementary with other research methodologies. At the end, an adapted and integrated multi-method approach is more plausible to generate fruitful research results. As a premise, research contributions can arise from systems development, experimentations and performance test of developed systems, and all these research approaches are necessary to investigate different aspects of the research work.

The participation of stakeholders linked with the Textile and Apparel industry seems to be one of the very few, if not the only way to depict the industry and come up with a valid model. The research cannot be performance tested except through the process of mediation and expert opinions. Since the development of the model involved stakeholders from the industry, this method improved both user participation in system development and the communication among the participants as well. Unfortunately, these are the same methods used for model building and therefore, there is a validation problem. In fact, the logic of the models developed and their coherence needs to be used as a proxy for external validation as the only other method is long term observation over decades. To mitigate this issue of validation, the same process was used in the development of the model as each group of experts logically analyses the models of the others for validation.

The different stages used in the mediated modelling process for collecting data and constructing the artifact are summarized in Fig. 2 below:

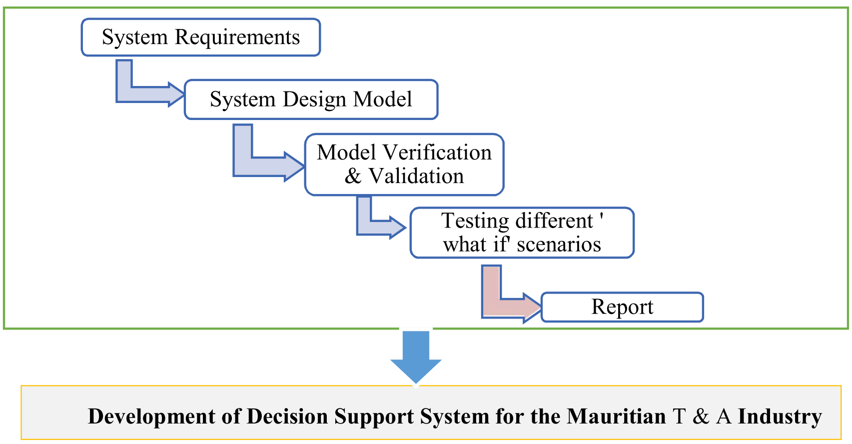

Fig. 1. Methodology for modelling the Mauritius Textile and Apparel Industry.

Fig. 2. Stages of mediated modelling process.

4. Model construction

4.1. Modelling the Mauritian Textile & apparel industry

This present research attempts to produce an artifact illustrating all the functions and activities having a major influence on the Mauritian Textile and Apparel Industry with regards to sustainability. The system boundaries set was to focus mainly on the materials and land components affecting the industry. System Dynamics was considered to be the most appropriate system-modelling tool for the modelling exercise. This was done using the STELLA 10.1 Software. The model that was the most representative of the most common activities of the Textile and Apparel industry was constructed. This was achieved following the data collected about those important actions forming an inclusive part of the industry. The base model provided an overview of the functional activities, links and interactions between each activities making up the current Textile and Apparel industry. The methodology used in constructing the base model was Mediated Modelling. The outcome was to come up with a representative model of the Textile and Apparel industry for further investigation on how to bring SM concepts and practices in the industry, with regards to materials and land usage.

Sustainable Manufacturing can be defined as a holistic systems concept that aims at mitigating the effects of manufacturing goods on the availability of resources by making use of the innovative designs, concepts, methods and technologies without compromising the life of future generations on the planet'. This adds up to the conclusion made by Despeisse et al. [38] that the concepts of SM practices are slowly and clearly taking place within the industry. In recent years, business modelling has received much attention due to its importance in the fundamental logic of every organization [39]. The primary reason for using modelling is to offer support tools that assist the decision-making process in manufacturing. It is important that the dynamic environment of the industry is taken into consideration while modelling the same. Modelling should be able to provide a logical way of predicting process outcomes in situations other that those observed in supporting organizational decision-making. In fact, the goal of decision modelling has been to determine the optimal decision, to define different trade-offs between different outcomes inherent in a set of decisions, or to predict outcomes. Such models capture knowledge of how systems are built through interacting processes and how each process works. It often combines experimental observations, expertise and logic.

With the importance given to sustainability in manufacturing systems, it has become significant nowadays to integrate the green aspect while modelling SM systems. Recycling, recovery, and life cycle costs of materials, utilization, and the way products were disposed of after sale are also concerns that need to be addressed while modelling SM systems. This can also serve as a means to include technology with social actors at a system-level sustainability. Furthermore, results obtained from modelling SM systems will help organisations to meet design and production objectives taking into account the sustainability constructs.

System dynamics is suitable for modelling SM even though there has been restricted application over the years. Sustainability strategies on environmental, social and economic impact were tested by both models. The conclusion was that both model congregated even though the variance in modelling approaches was quite significant. The results also showed that to achieve a sustainable status, there should be a mix of environmental, economic as well as social aspects. Bottom-line, the basis is that the way a system behaves depends a lot on its structure. This implies a two phased process. Firstly, the model the cause and effects of elements related to the model has to be developed and then secondly it involves developing a quantitative model representing the flow rates, levels and delays, wherever applicable. The interconnections between elements need to be studied as well.

System dynamics provides the possibility of getting feedback from output which accrues as a result the decision making process related to changes, such as, anticipating the effect certain policies related to energy, water, materials, process technology etc. on the factory, environment or society. Bearing in mind the scope of this research work, the main focus was on the materials and land components.

4.1.1. Materials model

The different types of raw materials for the production of wearing apparel have been considered: fibers, yarns and fabrics. It important to note that most, if not all, of these are imported. Hence, it would be interesting to consider growing plants/fibers such as cotton, jute, hemp or bamboo in Mauritius in the future. This will help decreasing in a medium to long term, the country's dependency on imported materials, the most common being traditional and genetically modified cotton. In the same line, it is deemed important to understand the requirements for growing and harvesting these plants. Also, the climatic conditions required to grow these plants need to be looked upon.

The first main issue to consider would be to look for existing available lands on the island to grow these plants. Not only that, given that these raw materials need to be converted in the appropriate fibers to be used, there is a need for a conversion plant. Either new plots have to be considered or there is also the possibility of considering taking part of the current land which are already under sugar cane cultivation and convert them into areas to grow these plants. By creating new plantations as facilities for the new locally grown fibers, this will give opportunity to those unemployed people to aspire to get a job. This will vary from unskilled labour to work in the fields or as operator in the factor. For example, people can be working in the fields or in the factories, but also to all those support services that will be required, such as transport etc. Not only this will bring in benefits for the social environment in Mauritius, but it will also help to move forward the country's economy. Government will earn more in the form of taxes from these factories and can hence invest in the country's welfare, in education or developing the country's infrastructure.

The contribution of the sugar cane industry to the country's GDP has been declining over the past years. In 2012 the industry contributed up to Rs 3,696 M of the GDP to Rs 2,671 in 2015, showing a reduction of around Rs 1,025 M over these years. These figures clearly indicate that the industry is producing less and less sugar from locally planted sugar cane. In addition, only 41.6% of the land available in the country is occupied by agriculture including sugar cane plantation, among others. The effective area cultivated by sugar cane was 59,724 Hectares in 2011 and 55,371 Hectares in 2015 as compared to the 70,000 Hectares the industry used to occupy 10 years ago, in 2005 (CSO, 2015). So, these figures clearly indicate that much land is being given up by the sugar industry to other economic activities. Hence for the context of this research, this can be used as rationale to convert part of the lands occupied by the sugar industry to the plantation of natural fibers. So the availability of land would not be a problem.

Following the mediation, out of the possible natural fibers that can be grown locally, the debate was mainly centered on cotton or bamboo. Cotton, among different crops, is one of the plants that need a very high volume of water and hence contributes to freshwater ecosystems annihilations, both locally and globally. Although cotton fiber is sustainably sourced, the production of 1 kg of cotton fiber requires more than 20,000 L of water, accounting for 24% and 11% of the world's pesticide and cotton consumption, respectively. Cotton cultivation has been accused of destroying the ecosystems in various parts of the world (Bellon-Maurel et al., 2014). Another material that emerged from consultation with experts was bamboo. The latter is in this case considered as ultimate green material (Netravali, 2005) meeting the definition of renewable and sustainable raw materials with little impact to the environment (Zupin and Dimitocski, 2010). Hence the potential of growing Bamboo has cropped up to the fibers under consideration for this thesis.

4.1.1.1. Why bamboo?. Bamboo is known to be the fastest-growing woody plant in the world, and can gain up to four feet per day. Most of them are grown organically and in most places and require no irrigation or fertilizer. Bamboo is considered to be a notable and adaptable plant. For example, in Asia, bamboo has been used for many purposes, including cooking, construction, transportation, textiles and medicine. It's only recently the Western world has discovered the benefits offered by using bamboo, including the eco-friendly solutions to many of our modern needs. Bamboo is a simple and wonderful eco-friendly resource that brings tremendous benefits to our lifestyle and the environment. Bamboo has already been used in Patagonia in the textile industry and there is no reason why it cannot be grown in Mauritius.

- Bamboo is sustainable
- Bamboo is Eco Friendly
- Bamboo is Biodegradable
- Bamboo improves soils quality

4.1.1.2. Bamboo in clothing. Bamboo is a very resilient and durable fibers. At the same time, it feels good to the touch, soft and comfortable. Various studies have compared bamboo to cotton and polyester, and found it to be stronger, more absorbent and more hygroscopic than the more common Western materials. Tausif et al. (2015), in their comparative study of the mechanical and comfort properties of bamboo viscose as an eco-friendly alternative to traditional cotton fibers in polyester blended knits, concluded that it could replace blended fabrics. Higher strength, lower stiffness, lower heat resistance and similar moisture management properties for apparel and home textile applications. In addition, the following characteristics of bamboo make it suitable to be used as fabric in clothing:

- Bamboo is extremely soft and silky smooth to the touch, offering unparalleled comfort. Hypoallergenic-Eco-friendly bamboo fiber is non-irritating to the skin. Softer than many synthetics, bamboo is a natural solution for those with sensitive skin.
- Breathability and thermoregulation helps to stay comfortable in all weather conditions and also keep cool in summer and warm in winter. Bamboo is said to be even more absorbing than cotton, hence it can easily wick moisture away from the skin.

Table 2
Rationale for the main components of the Materials Model.

	Materials Model Components	Component type	Statement
1	Land for Bamboo	Converter	Available land and abandoned land from sugar cane plantation are considered in this model for planting bamboo plants. This is a direct input from the land model. It is taken as a fixed value in the initial model but will eventually change when the materials model is connected to the land model. If more land from abandoned sugar cane field are available and used for bamboo plantation, then the expected result is to see more fibers produced by the conversion plant. However, all this will be guided by the demand from the new bamboo market. For the sake of the model, the land converter is taken as a step graphical function over 24 years, with a maximum of 2000 ha. However this can vary depending on how much land the sugar cane industry is ready to give up for bamboo plantation as well as the demand for such products in the future
2	Bamboo Stems	Converter	This represents the amount of bamboo plants (stems) that can be harvested for onward use in the new bamboo industry. For the sake of the model, the yield of 55 tons of bamboo fibers per hectare of land are assumed to be produced (same as for bagasse).
3	Bamboo	Flow	This is the input of bamboo to be processed in the conversion plant for fiber production. It will directly depend on the amount of bamboo planted and harvested.
4	Bamboo Reservoir	Reservoir	The bamboo reservoir is where all bamboo that have been harvested will be sent, as an inflow. Then the bamboo will be sent for conversion to linen and rayon via B Fibre to linen converter and B Fibre to rayon converter. The whole process is expected generate jobs to many jobless people. This will include all the processes involved in the processing bamboo into fibers. For the sake of the model, it is a taken as a single entity. This will have direct impacts on the social, employment, economic, wastes as well as the energy models. The more land is used to plant bamboo, the more bamboo will be processed to be used by the textile industry in Mauritius. If the bamboo reservoir shows a negative value, this will mean that there is insufficient supply of bamboo. This will in turn mean that not enough land is cultivated with bamboo to satisfy the demand of bamboo products. By looking at these results in this model, this will give an indication of imbalance problems in the overall system. Hence this can assist in the decision making process.
5	Bamboo fibers	Flow	Once bamboo is received in the bamboo reservoir, it will be sent to the next reservoir as fibers. This has to be done through a conversion process: bamboo to fibers.
6	Bamboo to fibers conversion	Converter	This is the process where the bamboo stems are converted to fibers. For the model, it is assumed that there are 10% wastes from the conversion and the remaining 90% are bamboo fibers.
7	Bamboo to fibers capacity	Converter	3 tons of bamboo are required to produce 1 ton of bamboo fibers. Since the model is run over 24 years which makes most of the processes time-obligated, a step function graph showing incremental increase in the bamboo to fiber capacities over the years have been used. The demand of bamboo based products over the years will impede directly on the amount of bamboo that will be required for conversion, hence impacting on the amount of land to be converter to bamboo cultivation, among other direct factors.
8	Bamboo fibers for conversion reservoir	Reservoir	All the fibers produced are stocked at this reservoir. Then it shall be separated into the two main components: linen and rayon for onward use by the T&A industry. The results obtained when running the model will give an indication of the types of actions that will be required. For instance, a negative value shows that there are insufficient supply or capacity to grow and produce bamboo crops to be sent for conversion to fibers. The results obtained will show imbalances among elements in the system. This will help in identifying the problems and also propose corrective actions to prevent such issues in the future.
9	Bamboo wastes to energy	Flow	It is assumed that 10% of wastes are produced while converting the bamboo fibers. This is sent to be processed for energy production. This is considered in the energy model.
10	B Fibers Linen	Flow	This is the output from the bamboo conversion reservoir for onward processing and producing yarn. The latter will be sent as an input to the bamboo linen yarn reservoir.

The rationales for some of the main materials components used in building the model are summarized in the table below (see Table 2):

4.2. The land model

The sugar industry in Mauritius has been declining for a number of years and sugar cane fields are being abandoned. New economic uses for the land need to be explored in a systematic analysis. This should include economic, social and environmental impacts. Moreover, the consumption value of housing is higher than the sane area used for agriculture. Hence, it has been observed that much agricultural lands with sugar cane plantations have been converted either to residential or commercial areas. The fundamental relationship between value added and land use is only a crude indicator of the direction and strength of the economic forces driving changes in land-use patterns. Although other economic uses for the land could be considered, they are not included in the models developed (and therefore the scenarios) as this work is focusing on the textile and apparel industry simply as a proof of concept. All the models could be further developed given sufficient resources. Hence, since the sugar cane production has been going down over the years, it is to the advantage of the country to look for alternatives to make better use of the land. This research work explores the possibilities of using the remaining land and also a chunk of the land for sugar cane to grow bamboo or to use for the production of electricity from renewable sources such as wind and solar. It is up to the Mauritian government to find the right balance between profitability, political feasibility and long-term resilience. Some of the components considered for the land model are summarized in Table 3. The model for the land and materials for the textile and apparel industry in Mauritian, as shaped on the Stella software is depicted in Fig. 3 (see Fig. 4):

5. Model validation

Sargent [40], defined model validation as the justification that the model handles a satisfactory range of accuracy within which it is consistent with the model's intended use. Indeed, the best test of confidence is the knowledge that it has been carefully built up in conjunction with the objectives and the MM group, for the case of this research work. There are many approaches, methods, tests, and validation techniques used to verify and validate simulation models. It is important to review the key factors that affect both model verification and validation: whether the problem entity being modeled is observable, which means whether the data collected can be used to develop and validate the model [40]. Tsioptsias et al. [41] reviewed existing model validation literature with the aim of identifying existing validation approaches and types of test used to assess the model effectiveness. This research was conducted mainly because, even if there is a large body of literature on model validation, there exist very few convergences in terms of definitions, validity types and tests used.

The proposed model was populated with data currently available with regard to each element constituting the artifact. In a practical sense, the usefulness rather than the validity of the model is concerned. In fact, every model is slightly smaller than the object

Table 3
Rationale for the main components of the Land Model.

	Land Model Components	Component type	Statement
1	Total Land in Mauritius	Converter	This represents the total available land in Mauritius and this amounts to 186,500 Hectares. This is a very important component of the land available as this will determine the land available for sugar plantation and other possibilities in the country. It is taken as a fixed value in the model
2	Land available	Converter	This represents the amount of land that is currently available for the sugar cane and other cultivation. This is equal to around 40% of the total land available.
3	Initial land for sugar	Converter	This represents the land that has been earmarked and used for sugar cane cultivation. This equals to approximately 93% of the land available.
4	Other land	Converter	Other land represents the portion of land that is left from land available, after removing the land use by the sugar can industry. This research works investigates at the possibility of using this land for sustainable purposes such as growing bamboo to be used as raw materials, producing solar and wind energy to decrease the reliance on fossil fuels.
5	Current land for sugar	Converter	It has been observed that sugar exports have considerably decreased over the past years. Here a decrease of land dedicated to sugar cane cultivations is looked at. The rate of use of this land will largely depend on the demand of sugar in the future.
6	Land loss from sugar	Converter	The land loss from replacing sugar cane plantation will eventually be added to the other land component. A graphical function of land loss over years is used in this case.
7	Solar	Converter	This represents the amount of land that will be converted for placing solar panels for the production of solar energy. As a starting point, the other land portion is divided equally in three parts among solar, wind and bamboo.
8	Wind	Converter	As for solar, this components represents one third of the other land component for erecting a wind farm. This will boost up the production of wind energy and hence decrease the reliance on fossil fuels.
9	Bamboo 1	Converter	This represents the portion of land that will be used for the cultivation of bamboo plants. These will be used in the Materials model for the production of bamboo based raw materials for onward use by the textile and apparel industry.
10	Sugar per hectare	Converter	This represents the amount of sugar that can be produced from 1 ha of sugar cane cultivation. This is be an input to the finished sugar that will be sent to the bulk sugar terminal.

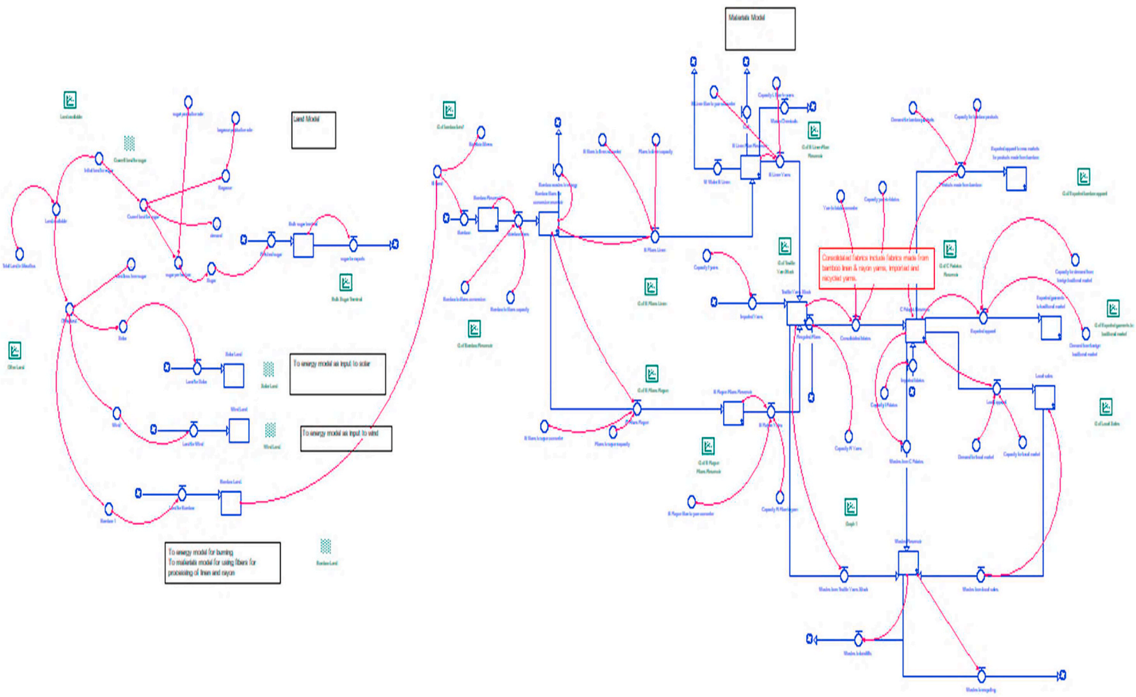

Fig. 3. The land and materials model for the mauritian textile & apparel industry.

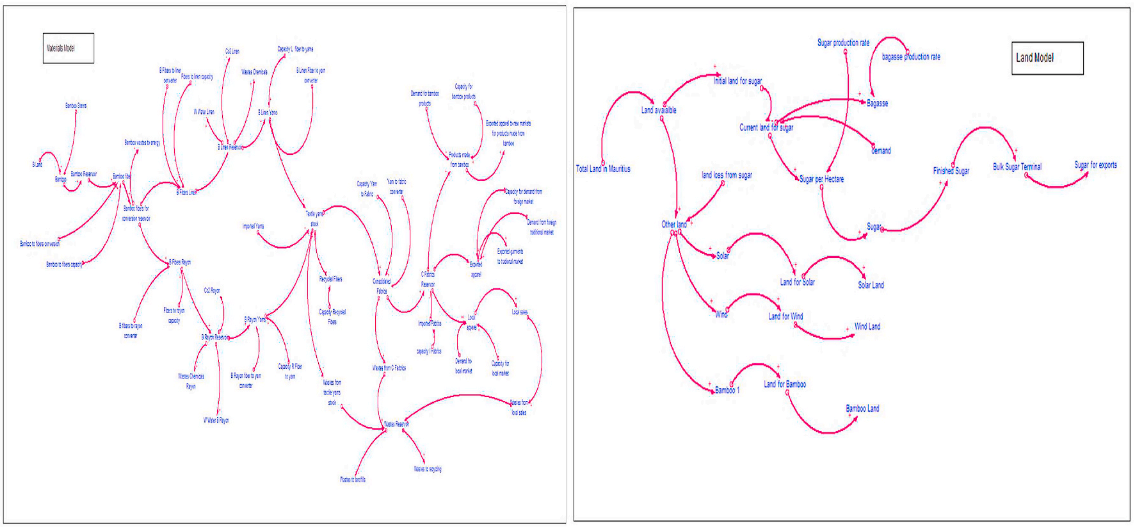

Fig. 4. Causal Loop Diagrams for the Land and Materials models.

of system being modeled, so no model is perfectly valid. Validity or usefulness is in the subjective view of the person using the model. Models can be considered as valid as and when they can be used with confidence. In addition, system dynamic modelling deals mostly with the conceptual or structural validation based on the successive, semi-formal, and formal, mostly qualitative process of building confidence in the conceptual structure of a model. The developed model in this research work is expected to show what will happen over twenty to twenty-five years in the industry. In fact, since it is a novel model, it is difficult to develop the required degree of correspondence of the dynamic model or generated behavior of the modeled system with the observed or expected behavior of the same system. For the validation of the model, the following questions were asked to all the participants:

- Has the problem been well understood?

- Has a suitable system boundary been chosen and understood?
- Has the new CLD been correctly translated to the proposed model?
- Have all the components been included?
- Does the model conform to the theory of dynamic systems?
- Can the model be compared with the real world?
- Does the model serve the purpose for which it was developed?
- Can the experts relate themselves with their respective fields in the overall model?
- Is the model a relevant representation of the current dynamics of the textile and apparel industry in Mauritius?
- Does the model behave logically when running?
- Can scenarios be run on the model?
- Do you agree with the model dimensions?
- Can the model provide you with a better knowledge about the dynamics of the Mauritian Textile and Apparel Industry?
- Can the proposed model be used as a decision support system tool for the Mauritian Textile and Apparel Industry?

The aim of mediation during the last workshops was mainly to get answers for all the above questions. Participants were invited to discuss and evaluate whatever was proposed in the new overall model. The main focus was to look at the implications and possibility of considering the Mauritian Textile and Apparel industry under the CE approach umbrella. It was deemed important to discuss how each new element would eventually be reused or recycled such that it comes back to the industry, so on and so forth.

6. Results and discussion

6.1. Scenarios running for the materials and land model

The land model was connected to the materials model through the bamboo land as an input to the production of bamboo to the bamboo reservoir. The amount of land to be used for bamboo cultivation will be influenced by the demand of such products. This will also impact on the investment that might be required for the construction of bamboo conversion plants, jobs creation, among others. The following assumptions were made while constructing the model, taking into consideration all the primary and secondary data that was available. This was done following consultations with experts from the Model Mediation Group. The main assumptions were as follows:

- The relationship between population and land use is directly related to the amount of arable land and the number of people fed by agricultural production in that area
- 60–70 tons of sugar per year can be produced on average. Since the model uses a monthly basis, then the sugar production rate is 5 tons per hectare per month.
- It is assumed that sugar production will continue in Mauritius but it will continue to decrease over the years. There may be a time when production becomes uneconomic and would cease altogether but it is not being considered in the scenario.
- The amount of uncultivated land that is suitable for growing bamboo is not known at this point in time. So, for the sake of proving the model, it will be assumed that all available land can cultivate bamboo.
- Although wind and solar farms need specific site conditions to be optimal, there is no survey data in the same way as the absence of survey data for bamboo cultivation. Again, for proof of concept, it is assumed that all land available could be used for wind and solar farms and for bamboo cultivation.

The rationale behind the modelling process is scenario planning to take a holistic view of the impacts of land availability as a PUSH variable and demand as a PULL variable. The imbalance between the two at any point in time is highlighted by the modelling process as is any other imbalance anywhere in the whole technical/socio-economic system, for instance capacity, investment and employment, among others. However, the number of possible states is infinite and true balance can never be achieved in reality. Therefore, boundary states are established using logic and experience from the Mediated Modelling group.

For the sake of this research work, two scenarios have been considered which is in fact based on the PUSH and the PULL strategy applied to introduction of bamboo as substitute material to cotton in the textile and apparel industry. The results from running the models can be used in assisting the decision making process on future strategies to adopt for the industry with regards to the introduction of bamboo in lieu of cotton.

The scenarios have been defined as follows:

6.1.1. Scenario 1: PUSH strategy

In this case, the use of bamboo will simply be pushed towards the textile and apparel industry. Relevant strategies aiming at making the industry and customers aware of the use of bamboo as a substitute product for cotton have to be devised and implemented. For this research work, the use of land for bamboo cultivation will be the factor that will be used to push bamboo as a new raw material for the textile industry. Hence, the amount of land taken from sugar cane and other use will be increased and be more than the land use for the development of wind farms or solar farms. The models can be used to investigate on the impact of this increase on other elements such as conversion plants, investment required, distribution channels, wastes generation etc. The results obtained when allocating half of the land available to bamboo plantation and the remaining half to wind and solar are discussed below.

The graph for remaining land, from land available, as shown in Fig. 5, termed as other land in the model shows an increase over the years. This is to be expected since, as discussed earlier in this research work, more and more land is being taken from direct sugar plantation to other use. This provides a good opportunity to explore new avenues of development and can benefit new industry such as bamboo, solar or wind. With the creation of these new industries, more jobs can be created and hence positively impacting on the country's economic situation. In this case, introducing more renewable resources such as wind and solar and also cutting down the reliance of the textile and apparel industry on the use of cotton as raw material. It is important to note that though the land can be made available, not all portions can be used for developing a solar farm or wind farms, which require locations with very specific conditions for the capture of sun or wind. However, bamboo plants are known to be able to grow in any conditions, even in arid land, which gives this plantation an edge while deciding on the quantum to be allocated. The sugar market is shrinking and hence the lands used by that industry can be used for the cultivation of bamboo.

For this research work, it has been proposed that the abandoned land by the sugar cane industry is shared among solar, wind and bamboo (Figs. 6–8). The ratio used for PUSHING bamboo to the textile and apparel industry in Mauritius is to have 50% of the land for its cultivation, and the remaining 50% shared equally between solar and wind. The amount of land use from the bamboo industry will be used to produce bamboo plants that will be eventually be transformed to linen and rayon and then used as raw materials in the textile industry, will feed the Materials model as well as the Wastes model following the wastes produced from the new industry.

It has also been proposed in the research work to use the wastes from bamboo to generate electricity, using the same basis as converting bagasse to electricity, and hence will feed the Energy model, as well. The amount of land dedicated to solar and wind for further developments in the production of renewable energies will feed in the Energy model. It is expected that the electricity produce will be sent to the national grid and hence reducing the reliance on fossil fuels for the production of electricity. Again, the output for the land allocation will normally depend on the demand as well. For instance, if there is more demand for bamboo based products, hence more land will have to be used for its cultivation and same applies for the solar and wind energy production. However, for this scenario and sake of this research work, more bamboo is being pushed to the industry since it is believed that this material can bring much benefits to the new textile industry.

The bamboo reservoir is expected to receive raw bamboo once it has been harvested from the land occupied by same. From the above graph, it can be seen that over the years more and more land is being utilized by the bamboo industry. In fact, the additional land required will be taken out from the current land occupied by the sugar cane industry, since the sugar market has been underlined over the past years and this trend is expected to continue, as depicted in Fig. 9.

From the graph in Fig. 10, the negative values give an indication that the processing capacity for fiber production is greater than the capacity for converting the fibers in either rayon or linen. This means that we are producing more bamboo than can be converted. One solution, based on the result above is that more investment is required in terms of building conversion plants if more bamboo is to be cultivated. The graph also shows that, with the current capacity, this will occur after around 18 years. Hence, there is sufficient time enough to invest and start building the new facility. Therefore, the model provides valid assistance to the government and the relevant stakeholders in the decision-making for the investment in a new plant. This can also be used as a justification to look for potential investors in this new industry (see Figs. 11 and 12).

In both cases, there will be an increase in the production of the conversion of fibers to rayon or linen, as confirmed by both graphs below with regards to the reservoirs of linen and rayon fiber reservoirs.

The products made from bamboo, with the current availability of this material, as proposed in this scenario will follow a step increase trend, as shown in the graph below. The model can be used, through the graphs from Figs. 13 and 14 to look for specific period of time where the amount of products made from bamboo is either stagnant, hence without any improvement. This can show that the capacity to produce the products with the available amount of bamboo raw materials might not be sufficient. Hence, decision about investing in new plants, or looking for new markets etc. can be taken (see Fig. 15).

6.1.2. Scenario 2: PULL strategy

In this strategy, the aim will be to generate interest and demand for the introduction and adoption of bamboo products by the potential customers (local and international). In fact, the customers will be the one to demand and drive the need for producing

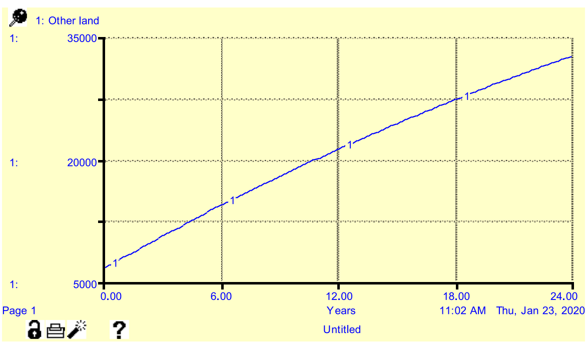

Fig. 5. Graph of remaining land over years.

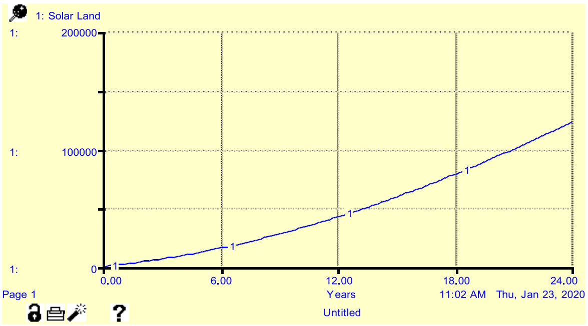

Fig. 6. Land use for solar farm over years.

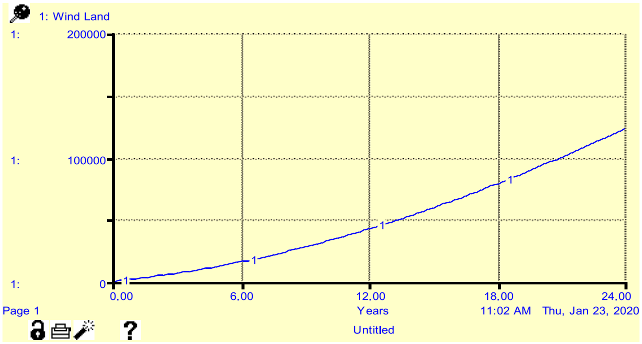

Fig. 7. Land use for wind farm over years.

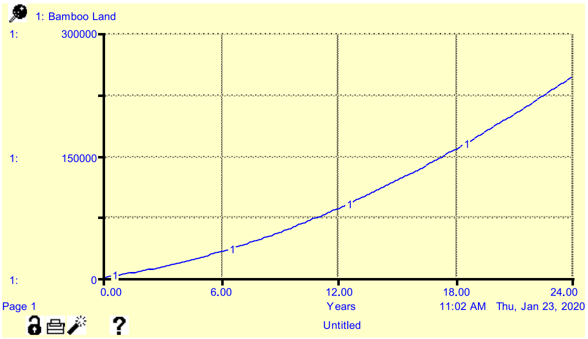

Fig. 8. Land use for bamboo cultivation over years.

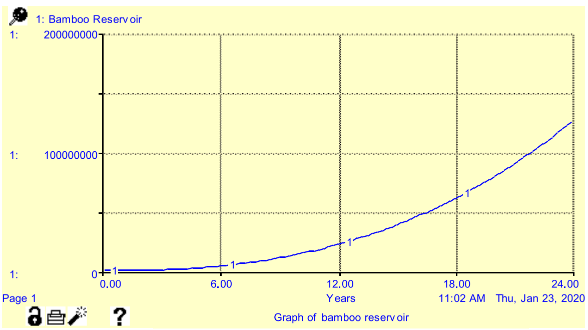

Fig. 9. Bamboo reservoirs over years.

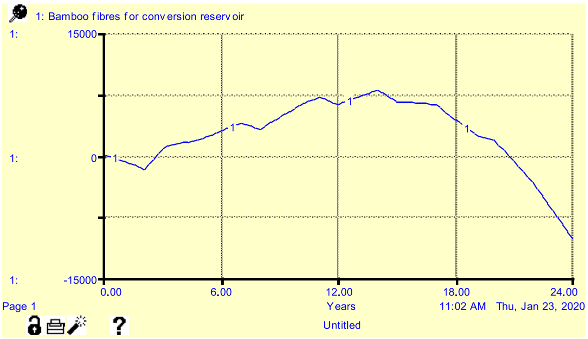

Fig. 10. Bamboo fiber conversion reservoirs over years.

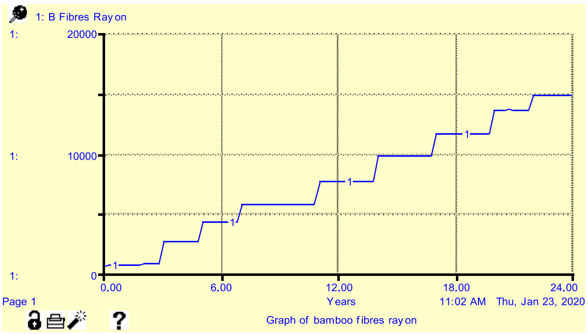

Fig. 11. Bamboo fibers rayon over years.

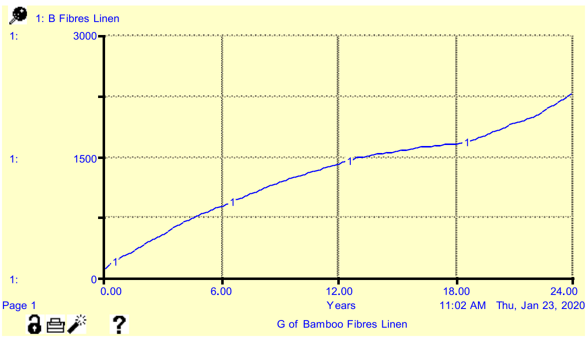

Fig. 12. Bamboo fibers rayon over years.

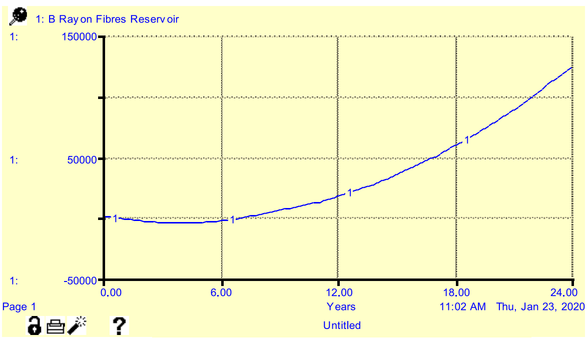

Fig. 13. Bamboo rayon fibers reservoir over years.

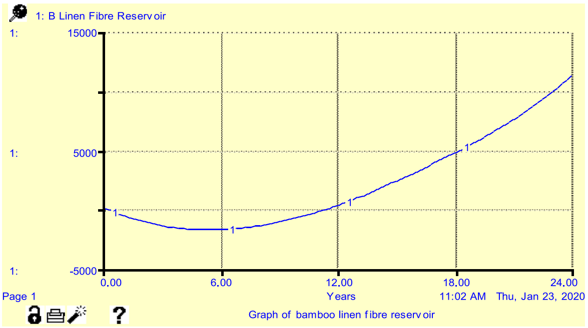

Fig. 14. Bamboo linen fibers reservoir over years.

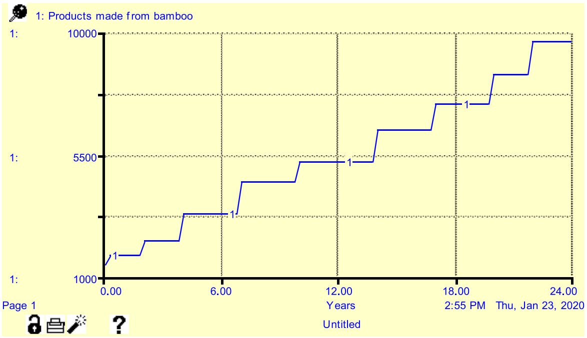

Fig. 15. Products made from bamboo over years.

bamboo-based products. It will be important to devise strategies whereby customer demands are intensified. This can be achieved through appropriate marketing campaigns, and using methods such as sensitization campaign on sustainability issues related to the use of conventional materials such as cotton in the textile and apparel industry. For this research work, the model will be used to see the impact of an increase in demand in bamboo based products. As a starting point, the land allocated to bamboo, solar and wind will be equally shared. The results obtained by keeping equal share of land, but with a subsequent increase in demand of bamboo based products are discussed below.

By looking at Figs. 16–18, it can be seen that the remaining land from the land available, apart from sugar cane plantation has equally been shared among bamboo, solar, and wind. The steady increase over years indicates that the land loss by the sugar cane industry will be ongoing (see Fig. 19).

As expected, the bamboo reservoir will decrease since less land dedicated for bamboo cultivation. However, as shown in the graph below, even though the amount of bamboo produced is less, the amount of bamboo produced is still greater than the amount of fiber being converted. This again shows the need for further investment on new conversion plants. This is logical, even more so with an increase in demand in bamboo based products from the customers' end.

By looking at the graph from Fig. 20, which provides details about the amount of consolidated fabrics stored over years. Consolidated fabrics for this research work include all types of fabrics made in the textile and apparel industry in Mauritius (cotton,

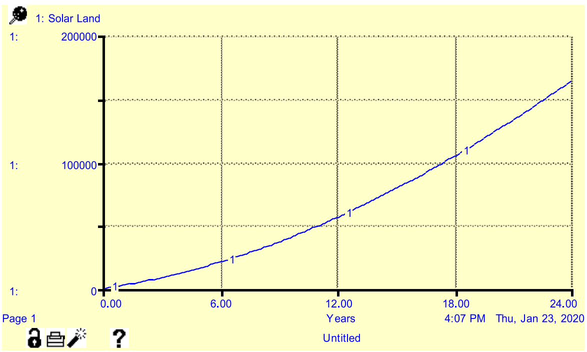

Fig. 16. Solar land use over years.

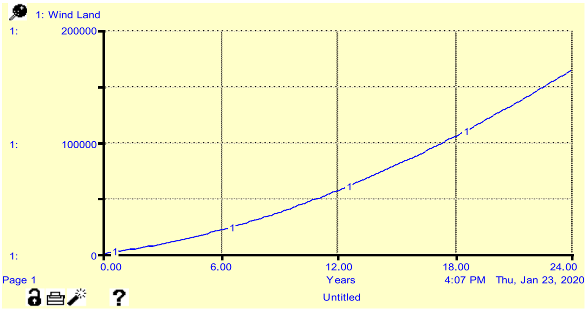

Fig. 17. Wind land use over years.

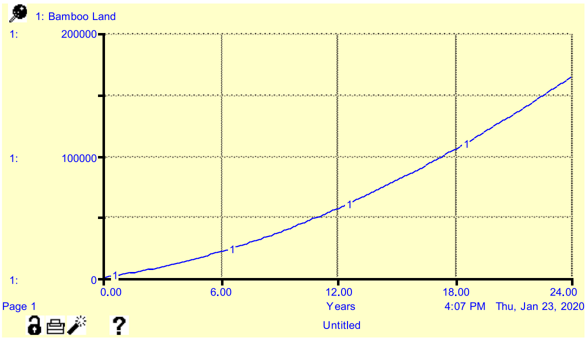

Fig. 18. Bamboo land use over years.

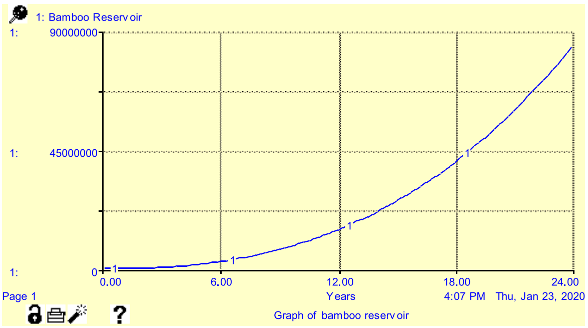

Fig. 19. Bamboo reservoirs over years.

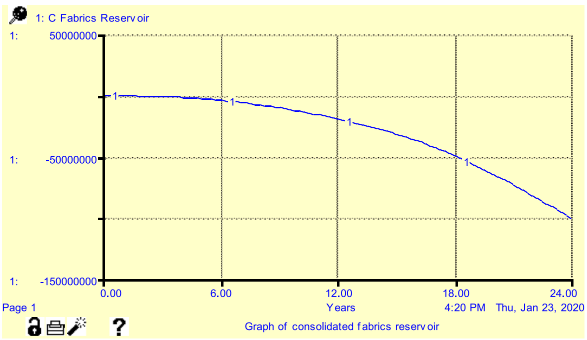

Fig. 20. Consolidated fabrics over years.

polyester, bamboo etc.). For this scenario, the demand of bamboo-based products has a considerable increase as compared to the others. The dip in the amount of fabrics stored starting from year 4 provides a clear-cut indication that the capacity used to grow bamboo as compared to the demand could not be maintained over the years. Hence, through this model, important decisions such as an increase in the land allocated to bamboo cultivation can be decided upon.

7. Conclusion

The current research work was conducted to contribute to the existing body of knowledge in the field of the development of decision support systems that incorporates SM concepts and practices. This research addresses the challenge of bringing sustainable manufacturing principles to the textile and garment industry in Mauritius through the university-industry collaboration. The research was centered on the use of land and the introduction of sustainable materials for the sector. From the literature review, it was observed that although efforts are being made to induce sustainability within the manufacturing sector in general, much remains to be done. The move towards sustainability, however, is not only in the hands of the stakeholders of the Mauritian Textile and Apparel industry; it needs the collaboration of each and every actor constituting the industry. This includes the Government and Policy makers, the suppliers, customers, markets, amongst others. In other words, the development of strategies incorporating sustainability requires a holistic approach. In addition, investment in cleaner technologies and materials need to be considered by manufacturing companies in the near future. This might require additional support from the stakeholders, mainly the government to help these companies embark in the sustainability journey.

The most challenging aspect of the research work was to come up with a proposed model representing the Mauritian Textile and Apparel industry, geared towards SM. This led to the development of models that eventually combine into a holistic model for the industry under study. The main focus was on land use and materials. System boundaries were set such that they were within the objectives earmarked for this research. The flows between sub models and the linkages between these models were clearly defined and justified. The strategies identified and developed in line with SM principles are largely debated and agreed upon by the focus group. The logic and flow of the models were also discussed and validated to ensure that they embrace the reality of things, as far as possible. Finally, "what if" scenarios were put ahead and the predicted outcome for the textile and apparel industry was discussed and investigated. The number of scenarios that can be tested through models can be numerous. The results obtained can be used in decision making process on the strategy to adopt to be able to cope with market change, demand, environmental, social as well as economic issues prevailing at specific periods. Despite the fact that valid rationales were provided for the choice of the scenarios, there possibility and risk of having an element of subjectivity was always there. Also for a more accurate and broader picture of the future of the Mauritian Textile and Apparel Industry, more scenarios and tests should be conducted on the model.

The outcome of this research paper can prove to be very helpful in providing support to academics, researchers, and industry practitioners working within the textile and apparel industry to integrate SM practices into their day-to-day operations. Also, the development of the decision support system can be used as an analytical tool by stakeholders in the industry to test the possibility and validity of adopting sustainable manufacturing practices. This can also assist in the decision-making process and development of policies and legislations with regards to sustainability in the industry. It can set out the provision of the basis for textile companies to embark on a circular economy approach. The concepts of value cycles linking markets, design, manufacture and logistics with technology, materials, business processes, legislations, social and cultural, economic and environmental impact was used to develop a holistic and multidisciplinary approach for the textile and apparel industry.

The decision models developed in this research work will, in addition, assist in decision making, also provide an overview of the potential results for any actions that can be initiated by the government or stakeholders for the Textile & Apparel industry. For instance, when real data are plugged in the models. It becomes easier to have an oversight on the impacts of the decision(s) taken on other players in the industry. Another example will be for the quantum of investment that might be required for the development of the bamboo industry. The models can be used to see whether one conversion plant, for instance, will be sufficient or not for the new industry to meet all the demands. The current research provides a macro analysis of the elements considered. It would be interesting to investigate, in the near future, the possibility of going into the micro side of things: that is to look at the operations of textile companies and the potential to implement SM practices.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.heliyon.2023.e12939.

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