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Sustainable enterprise modelling and simulation in a warehousing context

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Abstract

Purpose – The paper seeks to propose the concept of sustainable enterprise simulation models. The social, environmental and economic models are developed and simulated using iThink in the context of a warehousing and distribution company.

Design/methodology/approach – The paper has leveraged the systems dynamic paradigm to conduct sustainable enterprise modelling and iThink™ system to implement the models. It uses the design science research methodology for the proof of concept of the models and modelling processes. The models have been developed for a logistics management company and tested in the business settings. These models were finalised through a number of revisions and iterations of the design, develop, simulate and test and evaluate.

Findings – The paper addresses the interconnectivity between disparate sustainability dimensions for developing the models. The validity and usefulness of the sustainability models for the day-to-day decision making has been authenticated by the management of the warehousing organisation.

Originality/value – The paper implements system dynamics concepts of sustainability modelling and produces models of various sustainability dimensions which are original in nature and evolution. While the domain in which sustainable enterprise modelling was carried out was warehousing, the concepts and principles that were explored, developed and validated is applicable across most enterprises.

Keywords Modelling, Sustainable development, Warehousing

Paper type Research paper

1. Introduction

Sustainability has been receiving increasing attention from academics, consultants, government and non-governmental organisations (Starkey and Welford, 2001). It is a concept for integrating and balancing economic, environmental and social dimensions (WBCSD, 2003), commonly termed as triple bottom line (GRI, 2002), into decision making (Elkington, 1997). Sustainability requires a sustainable business model (Munasinghe, 1993) which needs to be supported by a roadmap (Ahmed, 2009) to achieving the present needs of society without compromising the opportunities of future generations (World Commission on Environment and Development, 1987). This had

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been viewed in the past as an optional model for businesses. This, however, is changing with the mandatory requirements now being introduced for many aspects of sustainable development and reporting in countries including Germany, France and New Zealand. Becoming sustainable has become a non-negotiable imperative for many organisations. Apart from the regulatory requirements, pressures from various stakeholders, interest groups and international bodies has made it imperative that organisations balance environmental and societal impacts with economic necessities (Choucri, 1993). Irrespective of whether they are in government, private or public sector, organisations are under increasing pressure to meet sustainability (Choucri, 1994; World Commission on Environment and Development, 1987) from international communities. Sustainability is now becoming a necessity as stakeholders and societies place higher expectations on companies, expecting them not only to be profitable businesses but also to be socially (Ansett, 2007) and environmentally responsible for their actions. Scarce resources and an endangered environment necessitates a business model that creates minimum impact on the materials and maximum benefit for societies without a long-term negative impact on the world's ecological systems (Baldrige National Quality Program, 2003; Ferguson *et al.*, 2003).

The clean and green image of many of the world's developed countries are now becoming fragile and their sustainability statuses are declining in many aspects of their production and consumption of goods and services. The World Business Council for Sustainable Development stresses that sustainability is not just an option but a requirement for many businesses (NZBCSD, 2002; WBCSD, 2003). While many companies have jumped onto the sustainability bandwagon, sustainability is still a relatively new concept to most businesses as far as strategy development, business process transformation and implementation are concerned. One of the key challenges of a sustainable business model is that it demands new and innovative choices and ways of thinking to deal with the dynamic relationships of economic, social and environmental issues. A move towards sustainable business is not easy as it requires several key shifts in the values (Shrivastava, 2000) and its operational management.

Sustainable business management emphasises minimum impact on the natural world and maximum benefit for society. Maintaining intergenerational equity (Cartwright and Craig, 2003; World Commission on Environment and Development, 1987) is the underpinning requirement of all development, manufacturing and consumption irrespective of governmental bodies, businesses or NGOs. In addition to a viable financial outcome from business management, each organisation needs to create value for employees and be prepared to respond to the potential environmental damage that can arise from manufacturing, technology and the globalisation of business activities. Global enterprises are the major sources of environmental problem and also part of the solution (Choucri, 1993). They extract resources, manufacture products and deliver services in a way that creates economic wealth for the corporation but threatens the natural environment. More and more vulnerable living species are threatened with extinction. Native land cover is changing, energy usage and solid waste are increasing and air quality is deteriorating every year. Our personal and social life is seriously threatened. The world's sustainability status is declining and it will struggle to provide an adequate standard of living in the future if current trends are not broken and if businesses and society do not stop and reverse the damage to the environment. Employee and community well-being, cultural rights, transparency and governance

are some of the important constructs of the social aspects of sustainable business. Influential organisational stakeholders such as governments, finance organisations, development partners, global and regional sustainability bodies, environmental and social bodies and experts such as academics, researchers and consultants believe that a sustainable business model is the solution to current problems (Ministry for the Environment, 2002).

Economic, environmental and social dimensions of businesses are interrelated (Figure 1) and any change in the objectives of a dimension greatly influences the other two dimensions. Therefore, if the company had considered each of the sustainability dimensions independently and made decisions without considering all possible consequences of their decisions, any attempt to become a sustainable business would be unsuccessful. The first step in transforming a company into a sustainable business is to develop a sustainability vision and sustainability strategies that include sustainability objectives. In order for business strategies to be successful, they need to be derived from the organisational resources and experiences (Lynch, 2005). However, current sustainability visions and strategies are mostly a personal vision of top management which are not realistically supported by the organisation's resources, processes and knowledge-base. This lack of consideration and poor execution is mainly owing to the lack of frameworks and tools which can foster a real understanding that each of the three dimensions are interrelated and demonstrate the dynamic relationships the three sustainability dimensions have with each other.

This paper explores sustainable warehouse modelling in the context of an organisation that provides storage and transportation services. We model the sustainability issues of warehouses in general and then apply it in particular to the firm under study. We close the paper with a brief description of the implementation of the models and the development of a system that enables us to monitor the triple bottom line scorecard.

2. Sustainable warehouse management

Sustainable supply chain management is the "Management of raw materials and services from suppliers to manufacturer/service provider to customer and back with improvement of the social and environmental impacts explicitly considered" (NZBCSD, 2003). Decreased barriers to trade and improved technology (Jorgensen and Knudsen, 2006) has allowed businesses and supply chains to expand across regions and countries, further increasing the need for the sustainable management of supply chains.

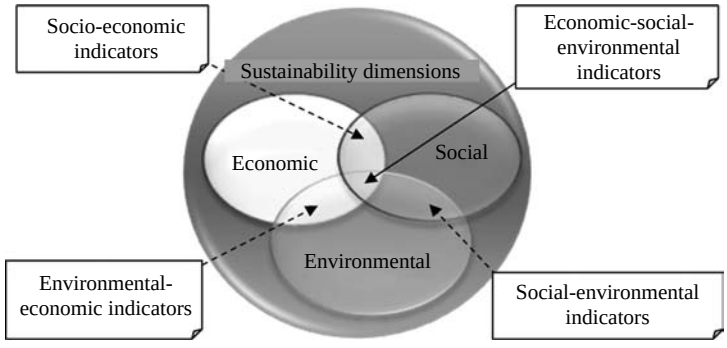


Figure 1.
Inter-relationship among the sustainability dimensions of the business

Furthermore, it is inadequate for businesses to promote sustainability only within their own company, entire supply chains have to be managed in a sustainable fashion in order for business to remain competitive. Benefits of sustainable supply chain management include increased brand appeal, sales loyalty and stakeholder satisfaction as well as reduced negative impacts on society and the environment (NZBCSD, 2003). Having a sustainable supply chain would also improve transparency and visibility along the chain allowing companies to be able to respond quickly to changes in the market and other situations.

One of the key components within the supply chain is warehousing. Most warehousing and transportation companies have little regard for the environmental impacts of their actions and do not understand the social consequences of their business activities. These companies consider factors such as cost effectiveness and customer satisfaction as the main performance indicators (Linton *et al.*, 2007; Quariguasi Frota Neto *et al.*, 2008). Both Linton *et al.* and Quariguasi Frota Neto *et al.* argue that being involved in the storage and transportation of goods, these companies have to recognise the importance of transforming their current business model into a sustainable one. An added impetus to the argument is that vehicle emissions are one of the major sources of pollution.

This research undertakes a real-life sustainable warehouse management project for an ISO certified warehousing company. The company provides storage facilities for chemical and food items in different regions for various customers and delivers the goods to manufacturers and retailers. Various small to large transportation companies are working in collaboration with the company in the transportation and delivery process. The warehousing company is growing rapidly and thus wishes to increase capacity by establishing more warehouses. The company's operations management processes are well-defined but due to shortage of skilled workforce, recent developments in health and safety, and environmental regulations as well as pressures from the sustainability aware members of its supply-chain, clients and the end-users, the company decided to redesign the business processes for the new warehouses that follow sustainability management approach and achieve competitive advantage within a short period. Major issues like employee retention, compliance and environmental footprints, and financial return are associated with the location of the warehouse. Therefore, the selection of warehouse location is an important strategic issue that would have a major impact on economic, environment and social dimensions of the entire management of the business. We highlight some of these issues in the remaining part of this section.

Owing to the nature of the goods handled, the company has to meet a large variety and number of compliance regulations such as health and safety, hazardous goods storage and handling, food items storage and handling, environmental compliance to name a few. It is obligatory for all employees to be highly trained in the compliance processes. Thus, it is hard to recruit skilled employees ranging from managers to warehouse operators who are needed to handle the chemical and food items. Ideally, the company would want zero employee turnover in order to minimise new staff training costs and achieve beyond the statutory compliance obligations to become a leader in the niche market.

Currently, the company's distribution system is entirely dependent on the road transportation network. Vehicle pollution is one of the biggest causes of environmental pollution, thus in the effort towards becoming a sustainable business, the warehouse

should be located such that the pollution generated is minimised. This can be achieved by either locating closer to the end-users or in a place that enables them to utilise alternative forms of environment friendly transportation. In the pursuance of providing maximum stakeholder satisfaction, the company also intends to invest a good proportion of their budget in information and decision support systems to aid effective decision making. The major stakeholders of the company are customers, retail/ manufacturing centres, end consumers, transportation companies, consultants, accountants, employees and government departments.

With the aim of helping the company become a leading sustainable warehouse management company, the authors undertook a research project to develop a sustainability systems model. While keeping the issues discussed earlier in mind, this model will be used to simulate and analyse sustainability key performance indicators determined from the critical success factors of a sustainable warehouse. The model will also support them in strategic decision making towards becoming a leading sustainable warehouse management company.

A sustainable warehousing company would not only have to consider the economic factors, such as rent and operations costs, but also balance the social and environmental effects that occur within the warehouse compound as well as its surrounding vicinity. This research places an emphasis on developing a balanced scorecard in conjunction with a sustainability model to help select a suitable location for a warehouse. The selection depends on the supply and delivery locations of the customers and the end-users, transportation choices to and from the warehouse, and skilled staff availability and their job satisfaction.

3. Modelling the sustainable warehouse

The sustainable warehouse management system can easily be broken down into simpler and more manageable parts for modelling (van Es, 1998). However, modelling in isolation is not sufficient; it is the relationship and interaction between the parts that are important (Ahmed and Sundaram, 2007). Sustainability models can be developed using a systems thinking approach and this helps in shifting the focus from individual effects to interconnected systems (Ferguson *et al.*, 2003) to shape organisations and their processes. Therefore, the sustainable warehouse management model needs to address the inter-relationships of economic objectives, employee welfare and minimisation of environmental impacts in an integrated fashion.

Maani and Cavana (2000) observe that the study and management of a complex feedback system can only be done using system dynamics/systems thinking modelling methodologies. Only the study of the system as a whole will lead to effective solutions and establish a win-win-win proposition for the three dimensions. Therefore, iThink™, a modelling tool that supports system dynamics, was chosen. iThink™ is useful for modelling dynamic relationships such as social issues (e.g. health, safety, recruitment, retention, working hours, wage, job satisfaction, training, etc.); environmental issues (e.g. carbon minimisation, recycling, solid waste, air pollution, water pollution, etc.); and economic issues (e.g. capital investment, warehouse rent, transportation cost, handling cost, packaging, information systems, hire cost, etc.). First, a cause-effect diagram was constructed to demonstrate the interdependence among the various issues and present an influence diagram. Then, the relationships among the factors were established.

Subsequently, an interactive game which demonstrates the interdependent relationships between the three sustainability dimensions was created. This allows users to gain a better understanding of how a decision will affect each of the three sustainability dimensions.

While the warehouse's location was the main decision problem, other decision parameters were required to design a sustainable model. Some of the major decision parameters include:

- capital investment: to improve staff efficiency and reduce manual labour;
- number of employees: to ensure employees are not overworked;
- employee training: to ensure high employee productivity and effectiveness and continuous up skilling;
- carbon minimisation: carbon credits, planting trees and air filtering; and
- transportation decisions: various modes of transport have significant differences in carbon emissions.

A sustainability scorecard was created to monitor the status of various key sustainability performance indicators. Some of the main tracking parameters include cash flow, warehouse utilisation, carbon emissions and minimisations, order processing time, employee job satisfaction, Social and environmental impacts on surrounding areas (e.g. nearby residents).

4. High level view of sustainable warehouse management

Figure 2 shows a high-level view of a sustainable warehouse model. The interdependencies of the three sustainability dimensions are depicted by arrows cutting across dimensions. The tradeoffs and interdependent relationships are further discussed in Section 6.

In a warehouse, goods processing involves processing of inward goods and orders. The rate of processing is determined by the staff's level of job satisfaction and productivity. If the employees are not able to process the required orders, the customers' satisfaction

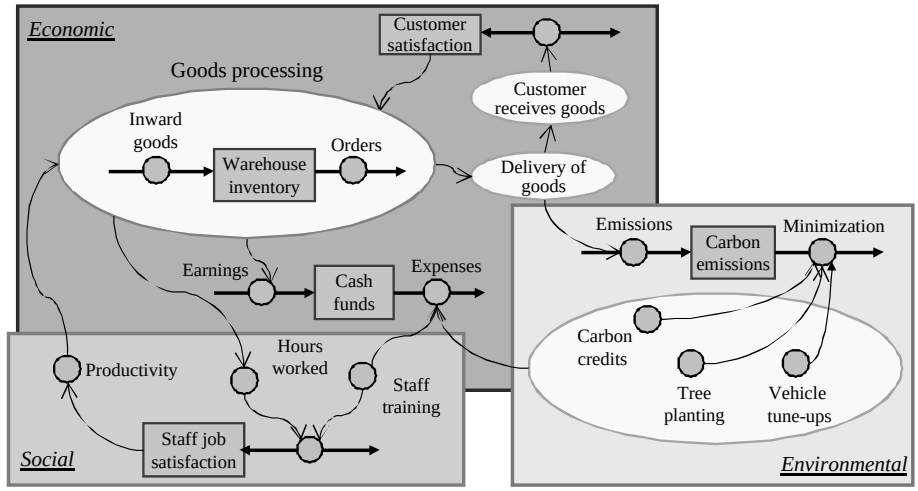
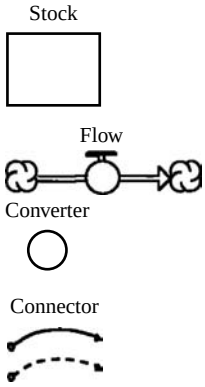


Figure 2.
High level view of a sustainable warehouse model

decreases leading to poor business relationships. Once the orders have been processed, they are transported to the customer's clients. The process of delivering goods to their destinations results in large amounts of carbon emissions produced by the transportation fleet. In order to offset the carbon emissions, at least one of the carbon minimisation activities will have to be performed, leading to an increase in costs.

5. System dynamics warehouse management models

This section discusses the individual dimensions of the warehouse management model that was developed using system dynamics modelling concepts. Before discussing the dynamics of a sustainable warehouse model, the purpose of each element used in the model is defined. In this instance, a stock and flow model was used to represent the sustainable warehouse model. Elements of a stock and flow model consist of: stocks, flows, converters and connectors. Each of these elements is further described below:



A stock represents the accumulation of either a physical or non-physical quantity, e.g. number of orders, customer satisfaction.

A flow represents an activity which fills up or depletes a stock. The arrow indicates the direction of positive flow into or out a stock.

A converter can hold values for constants or serve as an external input to the model or convert inputs into outputs through user-defined algebraic relationships or graphical functions.

Connectors provide the links between models elements. Solid wire is an action connector and dashed wire is an information connector.

5.1 The economic model

Figure 3 is a snapshot of the main economic model of a sustainable warehouse. The stock that is central to the economic model is warehouse inventory. When a customer sends an order to the warehouse, it is added to the order backlog. The number of staff (i.e. hours available for processing orders) and inventory on hand will determine the number of orders processed (orders filled) and delivered. Any orders that cannot be processed,

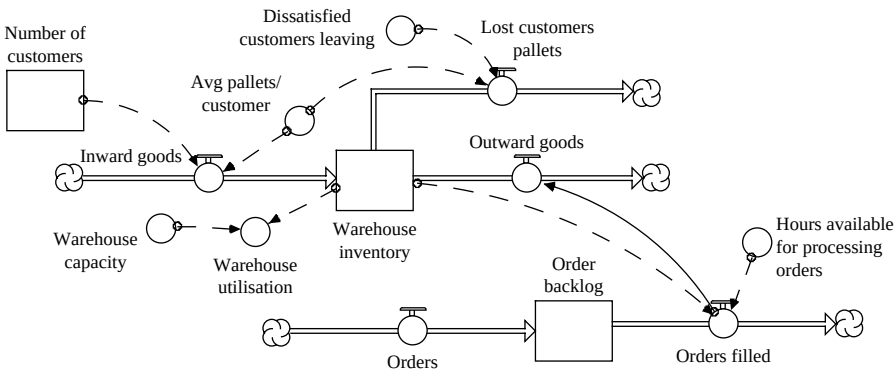


Figure 3.
Economic model of a sustainable warehouse

owing to the shortage of either staff or inventory, will remain in the order backlog until the next run. Warehouse utilisation which considers the effectiveness and efficiency of space usage is also an important economic factor to monitor in the warehousing business.

The warehouse company wants to maintain a high-capacity utilisation rate to ensure maximum profits. Thus, if utilisation is consistently low, it is an indication that the company should seek to obtain new customers by means of promotions or advertising. On the other hand, if the warehouse is over utilised, the company will have to consider increasing their warehouse capacity or rent short-term storage facilities for excess inventory at a greater than average cost. The company should also try to maintain a high level of customer satisfaction by ensuring that goods are delivered on time or the company might run the risk of losing some of their customers.

5.2 The environmental model

A high level model showing a few factors that influences the environmental dimension is shown in Figure 4. This model shows the main inflows (emissions) and outflows (minimisations) of the carbon emissions stock. Carbon emissions (total transportation emissions) are generated by the company's transportation fleet comprising of vans, small and large trucks. As the vehicles are highly utilised, their efficiency deteriorates over time thus producing higher levels of carbon emissions. The warehouse company can minimise this by regularly maintaining and upgrading their vehicles (transportation fleet upgraded). The company may offset their carbon emissions by planting trees (carbon absorption by trees) or purchasing carbon credits.

5.3 The social model

The social dimension of the sustainable warehouse is very complex and contains many elements. For the sake of simplicity, a simplified social dimension model is shown in Figure 5. This model represents the social effects of a warehousing company with

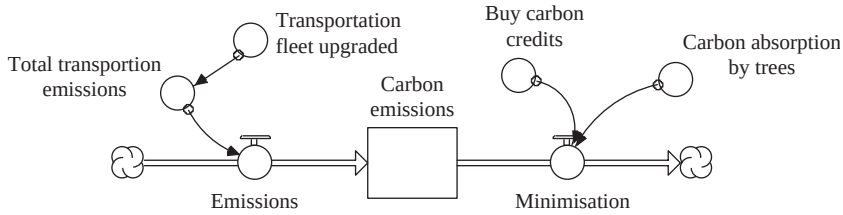


Figure 4.
Environmental model of a sustainable warehouse

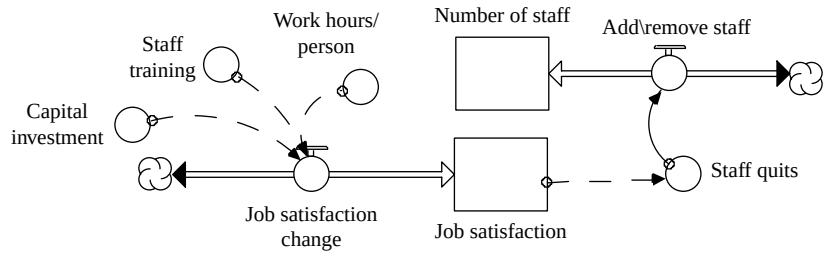


Figure 5.
Social model of the sustainable warehouse

respect to its employees. The main stock in this model is job satisfaction. It is an index which has a maximum value of 100. The job satisfaction of the warehouse employees is very important. This will be discussed further in Section 6.

Factors such as hours per employee per week (work hours/person), the amount of staff training and support provided and capital investments, like new equipment and software to aid employees in their work, all have an effect on their level of job satisfaction. If employee job satisfaction drops below a certain level, staff members start to leave the company, resulting in having to hire more staff, thus incurring recruiting and new staff training costs.

6. Interactions between the sustainability models/dimensions

Having briefly discussed the inter-relationships of the sustainability dimensions in Section 4 and Figure 2, this section is dedicated to demonstrating some of the relationships between the three sustainability dimensions in the sustainable warehouse model.

6.1 Environmental-economic-social

In order for the company to move towards sustainability, they have to consider and balance the tradeoffs between minimizing costs as well as being both environmentally and socially responsible. As previously shown in Figure 4, so as to offset their carbon emissions, the company will have to purchase carbon credits, plant trees or minimise the emissions from their transportation fleet. All three carbon minimisation options will increase their expenses, which might lead to lesser funds being made available for staff training and capital investments. Inadequate staff training and capital investments will lead to poor job satisfaction and low productivity. This is further discussed in Section 6.2.

Another factor the company needs to consider is that the trees will require a couple of decades before they are able to provide the full benefits of carbon absorption. Thus, they may wish to consider purchasing carbon credits as a short-term solution while planting trees as the long term but more cost effective solution. In either case, the company should minimise inevitable carbon emissions by maintaining vehicle efficiency as it is important to consider the effects of carbon emissions on society, especially in areas along delivery routes.

6.2 Social-economic

Following on from Section 6.1, choosing not to hire more staff when required might result in short-term savings but will be detrimental to the company in the long run. This is because, the number of staff determines, on average, the number of hours available for processing orders. Thus, a shortage of staff will result in employees having to work excessive hours over a long period of time to try reduce the order backlog. This results in decreased job satisfaction owing to increased stress and tiredness. Poor job satisfaction will also lead to low morale and higher risks of making mistakes, therefore causing a drop in overall productivity. A drop in productivity means the average order processing time also rises, further increasing the order backlog.

High levels of backlog will lead to poor customer satisfaction and retention. If a customer is lost, not only will the company have to spend more money finding new customers, the loss of reputation and increased negative word of mouth will have harmful long-term effects.

7. Implementation of the sustainable warehouse models

To implement the models, the modelling software tool iThink 9.0.2, from iSee Systems, was used. iThink uses stock and flow diagrams to model and simulate processes and scenarios. It shows you the outcomes of certain user-defined inputs and communicates the interdependencies between processes and problems. Outputs can be displayed in the form of graphs, tables and warning gauges. In this instance, dynamic systems modelling techniques were used in the creation of this model. The process of creating the model in iThink was an iterative process. It started with a very simple warehouse inventory model (Figure 3) consisting of one stock (warehouse inventory), one inflow (inward goods) and one outflow (outward goods). This model was then tested to ensure that the relationships defined were correct. Once, this was verified, more elements such as order backlog and number of customers were added. Again this was tested before new elements were added. The whole process of building the entire model was carried out in this manner to allow ease in identifying errors in the model.

7.1 System walkthrough

Figure 6 shows the main user interface of the simulation model. There are six main sections on this user interface; the sustainability scorecard, the economic inputs, the social inputs, the environmental inputs, the comparative charts and the run section.

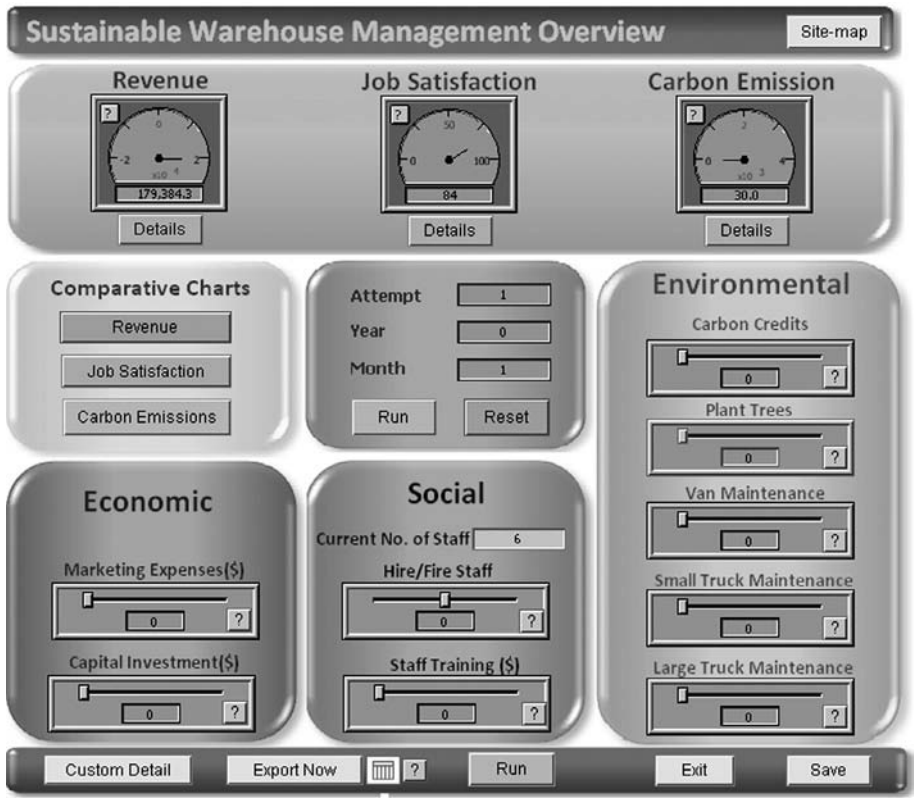


Figure 6.
The sustainable warehouse management simulation interface

The sustainability scorecard consists of three indicators; revenue, job satisfaction and carbon emissions. Revenue is the average revenue from all three locations. If the decision maker clicks on details, the decision maker sees another page with the individual components that affect revenue. Thus, if revenue enters the "High Alert" (red) stage, the decision maker is then able to drill further down into the details to determine which type of expenses was causing a drain in finances. For example, the warehouse may have been paying too many employees while there is little work to be carried out. This indicates that the decision maker might have to fire an employee to reduce costs. The decision maker can carry out the same operations for the social indicator, job satisfaction and the environmental indicator, carbon emissions. The decision maker also has the option, at any time, of reviewing previous simulation results for the three main indicators by choosing one of the choices in comparative charts. The custom detail button leads the decision maker to a page where they would be able to customise their own graphs or data tables.

The economic input section allows the decision maker to determine the amount of marketing expenses (to obtain new customers) and capital investment for each month. These values are reset to zero after each month. The social input section allows the decision maker to define the level of staff training available to improve job satisfaction and hire or fire staff according to the amount of work available. In the environmental section, the decision maker buys carbon credits or plants trees to offset their carbon emissions. They are able to optimise the efficiency of their transportation fleet by choosing a transport mode to upgrade or enforce a new selection rule for the transportation company. To begin the simulation, the user chooses all the values of the inputs that are desired, and then clicks the run button. The simulation runs for one quarter and pauses to allow the user to review the effects of the decisions made. The next few subsections will discuss the prototype in more detail.

7.2 Economic indicators

The economic indicators page, as seen in Figure 7, provides the decision maker with more economic indicators to help monitor and assess the situation. This page will display a line chart of revenue, income and expenses. This visualisation will allow decision makers to gain a better understanding and view of how the financial situation has changed over time. In addition, indicators of customer satisfaction and warehouse utilisation are provided as well. Both these indicators considered economic factors as

Figure 7.
Some economic indicator pages

they have an impact on the company's financial status. For example, poor customer satisfaction will lead to customers leaving the company and taking their business to competitors. This will result in a decrease of income as well as an increase in expenses required to obtain new customers.

Poor warehouse utilisation, which could result from poor customer satisfaction, would mean that the warehouse company is not maximising their profit potential and would be incurring increased overhead costs per unit of storage used and reducing their cost efficiency. By clicking on customer satisfaction or warehouse utilisation "details", the decision maker would be led to a page with more details regarding customers and the warehouse. This page provides the decision maker with information such as order backlog, warehouse inventory, inward goods and outward goods. Although not shown, the decision maker can also view a more detailed breakdown of income and expenses on another page. The next subsection discusses the social indicator pages.

7.3 Social indicators

The three main social indicators consist of average processing time/pallet, hours/person/month and job satisfaction. Figure 8 shows the main social indicators page displaying the three values in the form of status dials and a line chart. The status dials change between red, yellow and green according to pre-defined limits. For example, the hours/person/month indicator turns Red when employees are working more than 55 h per week. This provides a visual aid to alert the decision maker about the seriousness of the situation. In addition, a pop-up message will appear to notify the user regardless of which page they are currently viewing.

A line chart, which plots these indicators, not only provides the decision maker with a visual aid but allows the decision maker to gain a better understanding of the relationships each of these indicators have with each other. For example, the line chart will clearly show, as the number of hours worked increases over the limit, employee job satisfaction starts to drop over time. The advanced settings: social page provides the more experienced decision maker with the ability to change lower level details and relationships. One such example is the relationship between staff training and productivity or the number of hours worked per month that is considered to be overtime (overtime cutoff). Advanced settings are also available for economic and environmental factors.

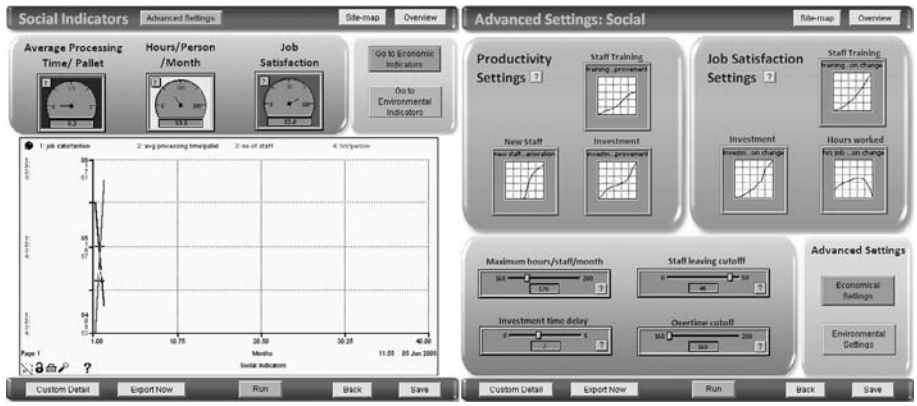


Figure 8.
Some social indicator pages

7.4 Environmental indicators

This subsection gives a brief discussion of the environmental indicator pages (Figure 9) in the sustainable warehouse management prototype. The main environmental indicators page shows the number of trees that have been planted as well as the number of trees ready to be sold. In order to support the decision maker, the number of trees required to offset current cumulated emission levels are also provided to guide the user towards making more effective decisions.

A similar guide is provided for carbon credits (i.e. carbon credits required to offset current cumulated emission levels). Similarly, visual aids are provided in the form of line charts. The vehicle details page provides the decision maker with details such as current vehicle emissions per distance travelled. Along with this information are the minimum levels (i.e. most fuel efficient) of carbon emissions for each vehicle type. This allows the users to make more informed decisions on which vehicle type requires maintenance. For example, if current van emissions are very close to the minimum possible emissions, then the decision maker will know that it would be a waste of money to perform maintenance on the van fleet. The money would be better utilised maintaining a less fuel efficient fleet or spent on other expenses that provide better value to the company in terms of economic, social or environmental terms.

8. Support for decision makers

As discussed in earlier sections, the prototype provides the decision maker with various forms of support that guide them through the decision making process. These guides range from the use of status alarms and notifications to the use of visual aids to enhance learning and understating of various relationships in the context of warehouse management. To aid the warehouse executives in making strategic decisions, the user interface of the sustainability model alerts the user with various notifications during the course of the simulation. For example, if the cash flow is low, a message pops up to notify the user that their cash flow is unsustainable. It also alerts the user if the employees are over worked; customer satisfaction level has decreased to a non-acceptable level; investment is required in employee training; warehouse location is not suitable considering the end-user location or capital investment; monthly operational costs and overheads are too high; high customer turnover or employee resignation owing to poor communication or handling, etc.

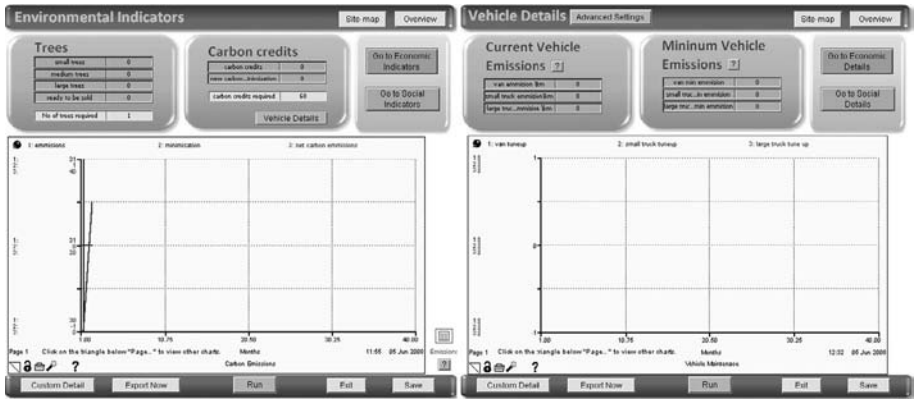


Figure 9.
Some environmental indicator pages

Usability and autonomy concepts were also kept in mind while designing the prototype and user interface. This prototype caters from novice users, who may only navigate through three or four main pages, to the expert users who may take advantage of the advanced functionality available in the prototype. The interface was kept simple and designed with ample "help" or "?" buttons that provide the decision makers with a description of various concepts or explanations to improve user autonomy. Colour templates as well as repeated and common items were kept consistent so as not to confuse the user and improve usability. For example, as seen in Figures 7-9, site-map, overview, run and save buttons were kept in the same locations of each page allowing decision makers to locate them easily and intuitively.

9. Conclusion and future research

A comprehensive representation of an enterprise is needed to understand its dynamic behaviour, processes, resources, internal and external stakeholders, and the constraints it must work within, and its relationship with the environment in which it operates. Models help us to manage complexity and to make substantiated decisions based on the well-understood and explicitly formulated essentials of the modelled situation. Enterprise modelling facilitates development of business strategy, conduct of business operations and design of information systems. It is accepted practice to break down the complex business system into manageable simpler parts for modelling. But modelling in isolation is not sufficient; it is the relationship and interaction between the parts that are important. A sustainability model is an integrated model of the environmental, social and economic dimensions of businesses that helps us to understand the complexities and impacts of sustainability issues. However, modelling these sustainability dimensions is not simple, as they do not have equal weight in the decision-making and operational processes. Modelling each dimension separately does not properly address sustainable development issues as they are interrelated as shown in Figure 1 and any change in one dimension influences the other two dimensions. Each dimension is again comprised of many sustainability issues and indicators and an issue/indicator may belong to one or more dimensions.

Such sustainable enterprise modelling allows us to manage organisations in a holistic manner that balances the economic realities with the social and environmental imperatives while maintaining intergenerational equity. Such a holistic modelling allows an enterprise to develop sustainable policies and strategies, identify problems and bottlenecks, assess various options for addressing the problems, consider interconnected issues and take into account the long-term pros and cons. But to be able to explore such issues, an environment that enables us to simulate the complex interdependencies between the social, economic and environmental dimensions is required. In this paper, we have leveraged the systems dynamic paradigm to conduct sustainable enterprise modelling and iThink™ system to implement the models. The paper has gone some distance in proving that it is possible to model the interconnectivity between disparate sustainability dimensions.

The validity and usefulness of the sustainability models for the day-to-day decision making has been authenticated by the management of the warehousing organisation. While the domain in which sustainable enterprise modelling was carried out was warehousing, the concepts and principles that were explored, developed and validated is applicable across most enterprises.

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