Eco-Factory Grand Challenge in the Centre for SMART

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Introduction

The 'Eco-Factory' Grand Challenge is part of the EPSRC Centre in Industrial Sustainability which is a collaborative initiative between Cambridge, Cranfield, and Loughborough University and Imperial College. It is one of the three key Grand Challenges being investigated in this Centre, together with 'Eco-Efficiency' and 'Sustainable Industrial Systems'.

The Eco-Factory Grand Challenge aims to investigate the next generation of methodologies, tools and technologies for future sustainable factories. The work in this Grand Challenge is based on four projects, three of which are led by Loughborough:

1. Resource Efficient Manufacturing
2. Zero Waste Factories
3. Eco-Intelligent Manufacturing

Built on SMART's strong background and experience in all areas of sustainable manufacturing – from design to end-of-life, and from production processes to supply chains – these key themes aim to address the most pressing challenges facing manufacturing companies now, and in the future.

Research in each of these areas will be focused on radically reducing the environmental impacts of future factories through development of both hardware and software solutions.

Sub-Project Areas

Each core project theme within the Eco-Factory Grand Challenge is composed of a number of strategic and complimentary, smaller sub-projects centred on three fundamental areas of:

- Technologies & Processes
- Monitoring & Modelling Methods
- Management & Control Tools

Within each theme, a combination of sub-projects will be defined to address the most pressing challenges at every level within an organisation, from operational to tactical and strategic considerations. The results from sub-projects and main project themes will then be validated and tested through industrial demonstrators and strategic case studies in close collaboration with project partners.

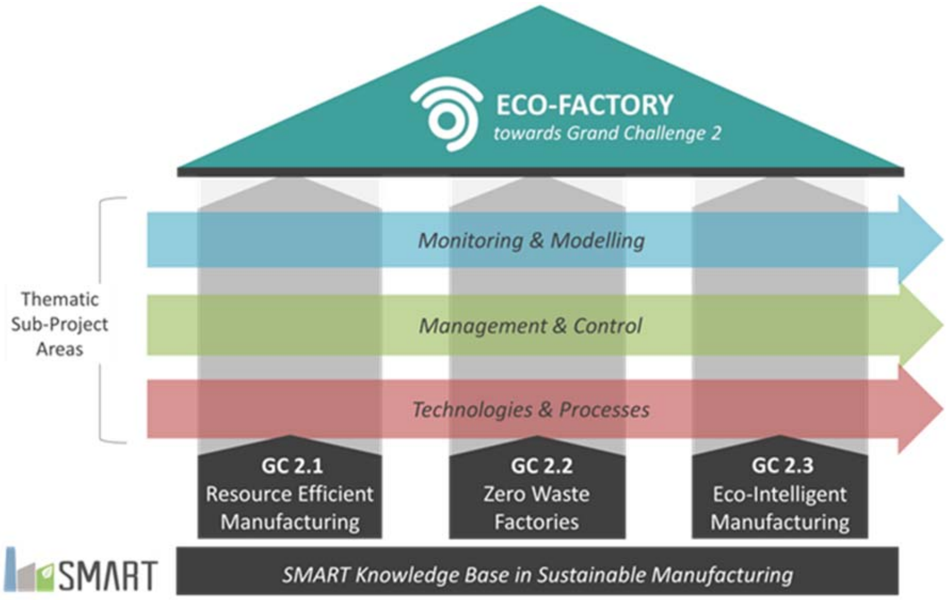

Figure 1. The Eco-Factory Grand Challenges at SMART

Material Efficient Manufacturing (MEM)

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[a]Lead Researcher, [b]Principal Investigator, [c]Co-Investigator

1. Introduction

There is a growing realisation that the current trajectory of increasing resource consumption within our finite global system is unsustainable. The economic resilience of manufacturing in the future will rely on actions being taken now to reduce both the rate of resource consumption and the environmental impacts associated with resource use. Materials are one of the key resources used by manufacturers, for example, in the case of consumer goods it is estimated that on average materials account for 50% of the production cost. The pursuit of Material Efficiency (ME) to decrease dependency in an uncertain future is of paramount importance for the stability, security and long term competitiveness of manufacturers.

The main objective of the MEM project, within the Eco-Factory Grand Challenge, is to improve manufacturing productivity, whilst reducing raw material consumption. MEM is fundamental to sustainable manufacturing and central to the UK's ability to maintain this sector and meet the increasing demands from consumers for manufactured products.

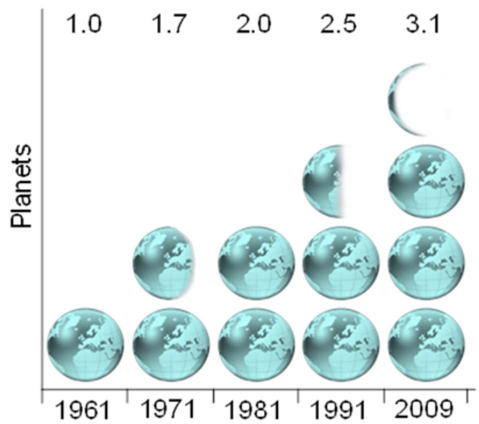

Figure 1. The ecological footprint of the UK has grown significantly since the 60's. This diagram illustrates how many planets are required to support the entire world if it was to have the UK's level of consumption. (The Consumption Explosion, new economics foundation, 2009).

2. Project Aims

This project aims to develop new proactive strategies, tools and technologies which support the efficient use of materials at a process, plant and factory level. As such, the following objectives have been set out:

- Develop novel technologies and processes to achieve ME improvements.
- Develop effective ME assessment frameworks and methodologies through material flow modelling approaches.
- Support strategic decision making in terms of the performance monitoring and management of ME.

3. Technology

A wide range of technologies for identification and characterisation of mixed materials are required to facilitate quality assurance, formulation and waste management. For example, infra-red imaging cameras have the potential for real-time monitoring of material flow. This could be used in various applications: to identify contaminating materials within a flow; to measure various material property changes; or to monitor compliance of materials and components with quality control standards.

An example of infrared (IR) camera utilisation is in the identification and partitioning of different materials via differences in thermal properties detectable by IR camera, as shown in Figure 2.

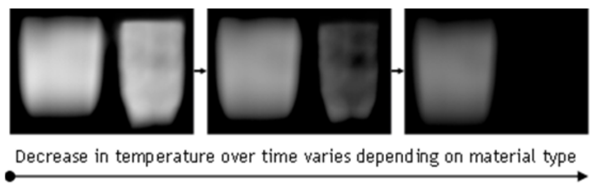

Figure 2. Infra-Red Imaging of PET and PLA plastic bottles, materials may be partitioned based on their characteristic thermal properties.

An IR camera could also be used to monitor raw material inputs, for example to measure material variance for real time formulation processes. Component inspection using this technique could also allow for early identification of material defects, before assembly.

4. Modelling

Material flow modelling in manufacturing is very complex. Production processes act on materials to transform them, resulting in combinations of materials, and potentially in variations in properties which change as the material progresses through production. Material Flow Modelling (MFM) is an approach to understanding material flow in a way that assists decision making by evaluating various strategies that may be employed to improve material efficiency in manufacturing.

MFM combines analysis of the quantitative flow of materials (mass, volume, etc.) with information related to the transformation of materials, which is often qualitative in nature and can be critical to fully understanding material flow. This can be used to accurately evaluate the efficiency and impact of material use, and the impact of waste generation.

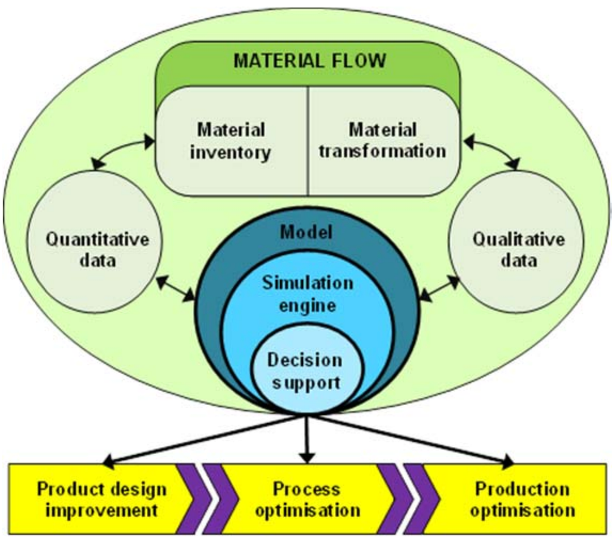

Figure 3. The material flow in manufacturing can be described using modelling techniques, which can be used to simulate production systems, giving decision support to improve product, process and production design.

Furthermore, the consequences of implementing alternative production strategies or designs can be evaluated through probabilistic simulation modelling. Thus, this approach can be used to improve the operation of existing manufacturing systems, and also to improve the design of future products and production processes.

5. Management

Whilst many businesses are interested in improving sustainability and lowering environmental impact, it is often unclear which Key Performance Indicators (KPIs) are the most appropriate and effective to help achieve this.

The ME KPI selector tool investigated in this project aims to assist manufacturers in selecting a powerful range of effective KPIs to drive forward their ME performance. This tool helps in the development of a bespoke portfolio of selected KPIs for a company, through coupling the typical material use and availability of monitoring data, to business strategies and environmental compliance standards.

This will allow manufacturers to monitor and manage ME by giving clarity to complex material flows and highlighting the most significant areas of efficiency variation.

6. Contact Information

To learn more about this grand challenge project or if you have ideas relevant to this project you would like to discuss, please contact Dr. Oliver Gould (O.J.Gould@lboro.ac.uk)

Alternatively, to become actively involved in this grand challenge project please contact Dr. James Colwill (J.A.Colwill@lboro.ac.uk)

Towards Zero Waste in Manufacturing

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1. Introduction

Current levels of waste generation are unsustainable and valuable resources are being lost to landfill, with limited progress being made towards achieving a 'closed-loop' manufacturing culture across various industrial sectors. Although many companies have taken on board the challenge to reduce waste with respect to their manufacturing activities, it has often only been due to a number of financial and legislative initiatives. These efforts to reduce waste have therefore only focused on the most cost effective solutions for disposing of waste, often without actually understanding their wider life-cycle impacts.

2. Project Aims

This project aims to investigate the methods, tools, technologies and processes required to support the long term goal of the Zero Waste Grand Challenge (ZWGC) by the manufacturing industry, whilst ensuring that environmental impacts of waste management activities over their entire life-cycle are understood and reduced. The following key research questions are being addressed in this project:

- What future recycling technologies would be required to deal with emerging complexity in design and material contents of modern products?
- How can waste generation associated to a product (or a component within a product) be modelled and monitored across the entire supply chain?
- Which metrics would provide simple and cost effective assessment methods for measuring the life cycle impact of current waste management practices?

3. Technology

Due to the large quantities and varying sizes and types of waste, current recycling technologies often rely on fragmentation and separation techniques and processes. These forms of large volume recycling activities are unable to recover small quantities of Strategically Important Materials (SIMs). To facilitate recycling of modern complex products which include varying amount and type of SIMs, the ZWGC project is developing novel technologies and processes to decrease the resources used by recycling processes, and increase recycling efficiency to recover SIMs.

One of the key areas of investigation in this project is to increase automation in recycling activities while improving recovery of sensitive materials such as Rare Earth Elements (REE), Precious Metals (PM), and composites. In this context, an automated robotic disassembly process is being investigated to improve concentration of the REE and PM prior to fragmentation processes (see figure 1).

Other areas being investigated are to enhance post-fragmentation recycling capabilities to effectively separate similar density materials utilising solid dense media separators, air pulse cascades and vibratory air pulse table separators.

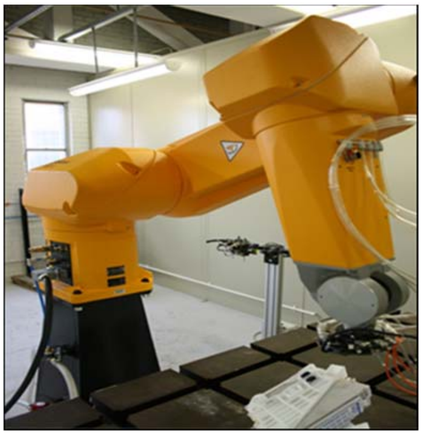

Figure 1: Robotic arm and component about to undergo automated robotic disassembly.

4. Modelling

Many companies today state they have significantly reduced or even eliminated waste within their factories, yet there is no apparent decrease in waste heading to landfill. This is often due to displacement of waste from OEM factories into various actors within their supply chain. In this context, it has been identified that there is inadequate support for companies to model waste flow across their entire supply chain. This area of research in the ZWGC project focuses on developing tools that enable the flow of waste associated to a product (or a component within a product) to be measured and monitored not only within a factory, but also across the supply chain.

This project is developing a set of standard waste categories and a number of simple procedures for waste data recording and generation of waste flow diagrams (see figure 2) which enable the visualisation of waste flows across a supply chain. This project will extend the scope of existing waste flow modelling, currently based on production processes within a manufacturing facility, to include the related activities at supply chain level. This will provide a holistic view of product waste and allowing companies to better manage their waste.

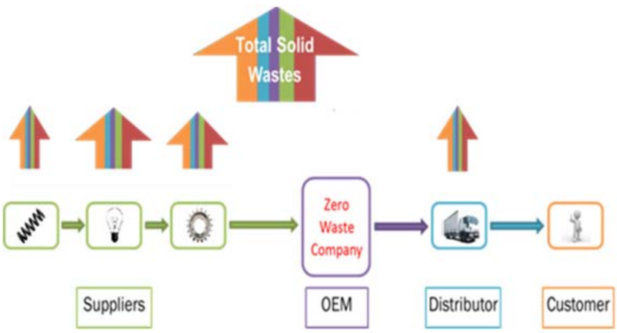

Figure 2: Example of how a supply chain Sankey diagram will be formed.

5. Management

Waste management decisions are typically based on cost and locality of appropriate facilities, with the environmental impact of the management option seldom considered. This is principally due to the high costs, length of time and specialist expertise required to gather the relevant data. Therefore awareness of environmental impacts of different waste management options is required to aid companies to make better informed decisions, as inadequate management leads to resources being wasted e.g. incineration of wastes with no energy recovery. This research area focuses on how to support the selection of the most appropriate waste management option for various waste streams, with the core concept of 'not every waste management option is environmentally or economically sound'. Investigations are being carried out to understand and assess the environmental and economic impact of current waste management options. This is to be achieved through development of a number of Key Performance Indicators (KPIs) to support principle decisions involved in the management of waste throughout the entire supply chain of a product. This will enable consideration of the environment during decision making and could be used in conjunction with existing economic and operational waste management processes (see figure 3).

Figure 3: Envisioned linking of Environmental metrics and KPIs with existing operational and economic management systems.

KPIs currently being considered and developed include:

- Value (£) of waste per tonne,
- Percentage of manufacturing waste material recycled,
- Recycled/recovered material use,
- Resources used to recycle,
- Percentage of waste sent to landfill or incinerator with/without energy recovery.

6. Contact Info

To learn more about this grand challenge project and discuss industry relevant research ideas please contact Dr. Michael Barwood (M.Barwood@lboro.ac.uk)

Alternatively, to become actively involved in this research grand challenge please contact Professor. Shahin Rahimifard (S.Rahimifard@lboro.ac.uk).

Eco-Intelligent Manufacturing

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[a]Lead Researcher, [b]Principal Investigator, [c]Co-Investigator

1. Introduction

Current manufacturing management systems and related decision making are optimised for cost effectiveness, time efficiency (output) and quality control. These utilize a complex network of data and information systems to enable manufacturers to remain competitive by making informed short-term decisions, and by generating forecasts for longer time scales. However, at present, environmental considerations are not routinely included in this decision-making, and it is becoming increasingly clear that their inclusion could lead to a significant reduction in environmental impact.

In this context, industry-relevant methods and tools are being developed as part of this project to enable the inclusion of environmental considerations within manufacturing planning, control and management over short, medium and long timescales as shown in Figure 1.

2. Project Aims

Physical changes to production machinery and manufacturing infrastructure can be costly and disruptive. Therefore, the primary aim of the project is to reduce the environmental impact of manufacturing companies through better informed decision making, reducing the need for heavy investment. To enable this, the following objectives have been defined:

- Identify, design and develop intelligent sensing and monitoring systems to improve resource utilisation.
- Develop and apply a number of Key Performance Indicators (KPIs) related to the environmental impacts of specific manufacturing activities.
- Establish an intelligent management and control system for environmentally focused long-term business decision making.

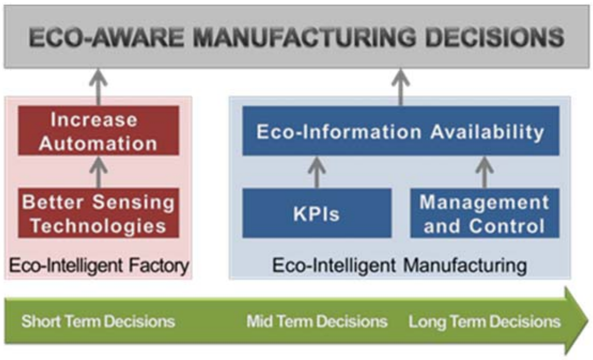

Figure 1. Eco-Intelligent Manufacturing Flow Chart

3. Technology

It is proposed that by accurately monitoring specific parameters for a wide range of manufacturing applications, it is possible to reduce associated environmental impacts (e.g. improve management of energy use). This project is therefore improving manufacturing technologies by the design and implementation of sensor process monitoring techniques which will allow near-real-time decision making. In this respect artificial intelligence techniques such as neural networks can employed in order to optimise, identify, and predict a range of relevant output variables and adjust manufacturing parameters accordingly.

An implementation of an infrared monitoring system has already been carried out on an aluminium milling process, in which tool state identification, and surface roughness assessment were the main objectives. Infrared signals were acquired, processed (see figure 2) and fed into a neural network based decision making support system. Using this technique, both the tool state and workpiece surface roughness could be identified with over 95% accuracy during the milling operation.

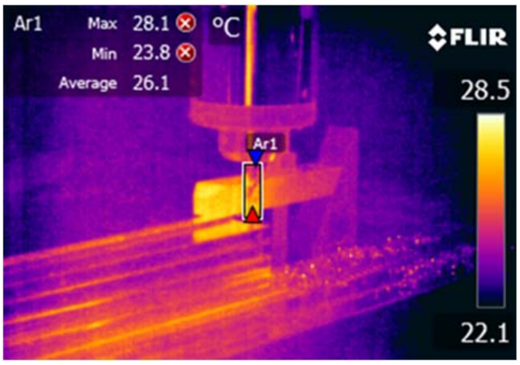

Figure 2. Infra-Red Monitoring of Milling Process

4. Modelling

This project explores the integration of environmental sustainability criteria into factory level decision making through the definition of relevant KPIs for improvement of planning decisions, such as production scheduling and inventory management. Where established management strategies exist, e.g. Economic Order Quantity (EOQ) for inventory management, these can be enhanced through the inclusion of environmental impact considerations for various inventory decisions. In order to facilitate inclusion of these additional factors, there is a need to develop corresponding environmental KPIs.

For example, in the food and pharmaceutical industries, the environmental impacts of inventory management presents a complex set of challenges, due to requirements for temperature-related storage and specific shelf lives. In these cases, the KPI Identification will be carried out by considering aspects such as: lead time, waste and disposal, energy, logistics and EOQ.

The subsequent modelling phase can then be carried out by applying advanced artificial intelligent techniques aimed at assessing, predicting, simulating and optimizing the environmental impact.

5. Management

Although the environmental impacts associated with manufacturing activities are well understood, the influence of various business models on the environment is not. This highlights the need to develop business management support tools for incorporating environmental considerations into long term decision making.

In this context, this project aims to extend the scope of existing tools, such as the Sustainability Balanced Scorecard (as shown in Figure 3) which is used to convert business strategies to specific actions, by evaluating the potential environmental impacts associated with the various actions. For example, by incorporating data automatically generated through the EOQ or intelligent process monitoring, this project seeks to improve the eco-awareness of future business models by balancing financial, technological and environmental aspects.

6. Contact Info

To learn more about this grand challenge project and discuss industry relevant research ideas please contact Dr. Alessandro Simeone (A.Simeone@lboro.ac.uk)

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Figure 3. Sustainability Balanced Scorecard Model