An Information–Centric Approach to Enterprise Modelling for Product Recovery

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Abstract

Recovery of used products and materials is becoming a field of rapidly growing importance. The scope and scale of product recovery have expanded tremendously over the past decade. Recent changes in government legislation in various countries and increasing customer awareness towards greener products have forced the manufacturers to rethink their business strategies. This has also resulted in new business opportunities in the area of remanufacturing and a large number of small and medium enterprises (SMEs) have appeared in the recovery industry. These SMEs include reprocessing and recycling companies as well as freight forwarders and warehousing companies.

Recovery firms have to deal with customer demands and returns that are largely dependant on the state of the art in technology. They change without any warnings and unfortunately a third party recovery firm has little control over them as compared to an original equipment manufacturer (OEM). In such situations, these companies must not only quickly adapt to the changes but also continuously evolve to survive in the market. They have to be versatile, changeable and able to quickly redesign and modify their own facilities and processes to cope with the changing situations. This paper presents an information–centred formal model for product recovery enterprises to aid the designers with modelling and evaluation tools to enable progressive design of the enterprise. The modelling exercise in this work involves description of the different views of the enterprise, namely strategic view, physical view, functional view and performance view. The analysis of the system (as part of the performance view) has been carried out using simulation.

Introduction

In the recent past, environmentally conscious practices in manufacturing have become an obligation to the environment and to society itself. Such practices are forced primarily by governmental regulations; however there is an increasing demand for "greener" products from customers as well. One of the major aspects within environmentally conscious manufacturing is product recovery, which is the transformation of used and discarded products into useful condition through re–use, re–manufacture and recycling. (Johnson & Wang, 1995) define the recovery process as a combination of remanufacture, reuse and recycle whereas (Thierry, Salomon, Van Nunen, & Van Wassenhove, L. N., 1995) divide recovery into repair, refurbish, remanufacture, cannibalize, and recycle.

Product recovery can be achieved in different ways. In general, two forms of recovery for the used products are commonly recognised, i.e. remanufacturing and recycling. Remanufacturing is recovering the product as a whole through a series of operations, which may include disassembly, replacing or repairing non–functional components, reconditioning, and reassembling (Fleischmann et al., 1997). Unlike repairing, remanufacturing includes disassembly of the product into components and turning them to like–new conditions before reassembling them. This may involve a number of cosmetic operations. Figure 1 shows a typical unit flow in remanufacturing. It is similar to the conventional production systems in that remanufacturing requires operational, manufacturing, inventory, distribution and marketing related decisions to be made. However, as this industry is more driven by the availability of raw material (used product) than by the demand of finished product (refurbished/remanufactured product); it involves high uncertainty. An OEM involved in recovery of its products can still plan ahead for recovery of its product as it will be aware of the technology and compatibility issues of its future products. Independent recovery companies, on the other hand, have little control over these matters. In addition, OEMs can change the market trend and demand through campaigns and promotion and these changes could be quite significant for SMEs involved in the recovery of the concerned product. In such scenarios, these SMEs need to reengineer their production and management systems to cope with the changing market and demand.

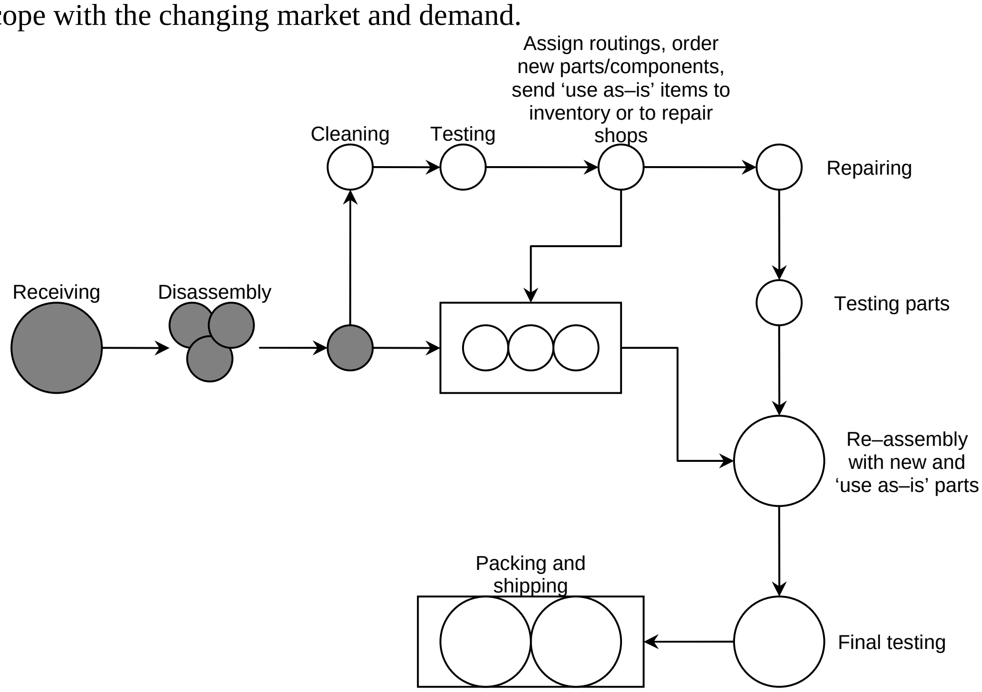

Figure 1: A typical unit (a product or a part) flow in remanufacturing [adopted from (Gungor & Gupta, 1999)]

Operational activities within a product recovery environment are different from traditional manufacturing activities. In general a high level of uncertainty regarding the timing, quality and quantity of returned product exists. Therefore, the level of agility and flexibility needs to be high. Collection of the used items and their packaging is one of the major issues in a product recovery environment (Livingstone & Sparks, 1994). Conventional manufacturing environments have a diverging effect distribution, i.e. the manufactured products delivered from a single source to multiple destinations. However, in a product recovery process, used products originate from multiple sources and are brought to a single product recovery facility. The logistic systems designed for such operations is commonly referred to as *reverse logistics* (Fleischmann et al., 1997). Like normal supply chain systems, reverse logistics need to address issues related to transportation, freight control, temporary storage, distribution, etc. However, the flow in reverse logistics is convergent unlike the normal supply chain which has a divergent flow. There is also an additional challenge as the source of the used products is the end–user and therefore there is a high uncertainty of availability of the product at the collection points.

Reverse Logistics is the movement of the goods from a consumer towards a producer in a channel of distribution. It defines a supply chain that should be designed to efficiently manage the flow of products or parts destined for remanufacturing, recycling, or disposal and to effectively utilise resources (Dowlatshahi, 2000). Reverse logistic focuses on managing flows of material, information and relationships for value addition as well as on proper disposal of products. For a large company, maintaining the reverse distribution of used products may be an easy task. However, for small and medium enterprises (SMEs), carrying out the logistic operations itself may create extra burdens. In such scenarios, the logistic operations need to be outsourced to companies called third party logistic providers. As a result, the recovery industry has largely been operated by small networked companies. The most common form of collaboration in the recovery industry is between the recovery and logistic companies, however in many cases, it is between contract recovery agents and OEMs. This kind of collaborative environment demands for a system where flow of required information among the actors should be facilitated keeping in mind the confidentiality of sensitive data.

Most business nowadays is highly competitive and ever changing. Recovery firms however have to deal with additional challenges, commonly processing a myriad of different used products originating from various sources. Customer demand and returns, which are largely dependant on the state of the art in technology, change without any warnings and unfortunately a third party recovery firm has little control over them as compared to an OEM. As a result, such companies must not only quickly adapt to the changes but also continuously evolve to survive in the market. They must be versatile, open to change and able to design and modify their own facilities and processes in parallel with new situations.

This paper presents an information–centred formal model for product recovery enterprises. The process of enterprise modelling is employed in order to create an abstraction of a complex business. Enterprise modelling provides designers with modelling and evaluation tools to enable progressive design of the enterprise. The use of an information–centric approach ensures that the business knowledge is conserved for reuse. It enables collection of valuable information throughout the design process to be shared by both management and designers. As discussed, SMEs in the recovery industry work in collaborative environments involving information exchange between the different entities within and outside the enterprise. Hence an information–centric approach becomes a necessity in such scenarios.

The modelling exercise in this work involves description of the different views of the enterprise, namely strategic view, physical view, functional view and performance view. The strategic view helps the management to build their business objectives, which in the case of a recovery company are greatly influenced by changes in legislation. The physical elements and resources in the system and their relationships are identified by the physical view. The functional view relates to the activities and associated decisions within the enterprise. Broadly, it involves acquisition of the returned product, recovery and logistics activities. Finally, the performance view helps management to determine whether the proposed enterprise can perform to the required level. For successful enterprise design or improvement, the designers need to understand the importance of each view and establish a suitable trade–off between them while using dynamic analysis methods for evaluation and reducing risks and improving confidence by testing potential changes through simulation and "what if?" experimentation.

The Modelling Approach

An enterprise model is a computational representation of the structures, activities, processes, information, resources, people, behaviour, goals and constraints within the enterprise (Fox & Gruninger, 1998). Enterprise modelling aids system engineers by allowing the analysis of the system by "what-if" experiments. It states the requirements and design specifications of the information system for distributed nature of decision making. The modelling approach used in this paper is adopted from the factory data model (Harding & Popplewell, 1999). Factory data model utilises an object oriented approach for its design.

Despite being different, all enterprises have common characteristics which can be captured in five base classes, viz. Process, Resource, Strategy, Facility and Token. The five classes are shown in Figure 4, where the clouds represent the object classes and the lines represent the relationships between them.

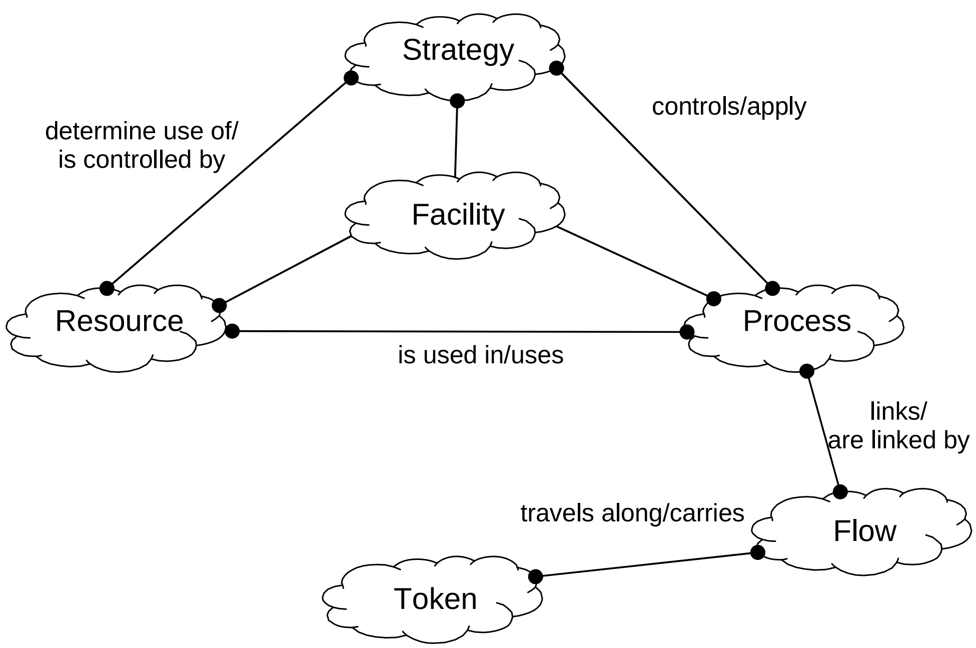

Figure 2: Key classes from factory data model [adopted from (Harding & Popplewell, 1999)]

Objects from the process class hierarchy capture functions, processes or activities within the business of the enterprise. Information describing and defining this class may include details of the process, other processes it may be a part of, duration, who/what is controlling it, its status, costs etc. The resource class hierarchy describes mechanisms capable of performing an action. Resource objects can range from human resources to machinery, tools, vehicles etc. the strategy class objects capture the knowledge and methods used to make decisions within different business levels. In real systems processes and resources are arranged into different facilities, related to business functions. Therefore objects from the facility class hierarchy have been included to help designers to view the organisation. The flow class objects connect independent processes and activities into a system with a purpose, while the objects from the token class represent the business objects that flow or move through the enterprise's system and processes. A detailed description of each of the main object classes can be found in (Harding & Popplewell, 1999) and (Yu, Harding, & Popplewell, 2000).

Implementation of the Modelling Approach

The implementation process is about the clarification of what is required, the generation of ideas, the analysis of the existing or possible systems, the comprehension of what already exists and how systems really work, the identification of possible design solutions and the evaluation of alternative solutions (Harding, Yu, & Popplewell, 1999). Different views of the system are presented so that the different perspectives of the design can be understood. Each view behaves in its own particular way and can support the design team at various different levels of abstraction.

The various viewpoints are represented with the aid of Unified Modelling Language (UML). UML is an object oriented modelling language containing a set of symbols. It also contains a group of syntactic, semantic and pragmatic rules (Noran, 1999). UML may be regarded the successor of the Object Oriented Analysis and Design methods that proliferated during '80s and '90s. In 1997, it became recognised and accepted as a potential notation standard by Object Management Group for modelling multiple perspectives of information systems (Booch, Rambaugh, & Jacobson, 1999). UML offers direct support for the design and implementation of each aspect of the information system and provides an integrated notation for their representation. In addition to supporting the main relationships between these representations, the application of the UML provides a natural migration process through the different development phases and perspective of the system, such as functionality, analysis and design, implementation, etc. (Costa, Harding, & Young, 2001)

The UML specification supports extensions and using which, (Eriksson & Penker, 1998) resent key business modelling concepts, including how to define business rules with UML's Object Constraint Language (OCL) and how to use business models with use cases. Using these extension, the business architects may add stereotypes and/or properties to the UML in order to suit their particular situations.

Strategic View

This view helps the management state their strategies as goals and objectives. It is used for validation as it states the business goals. Its helps the managers and designers by telling them what is required and how it should be performing. Then operational rules need to be determined and implemented. The strategic view should be revisited later in the design cycle, as the operational rules for defining priorities are required. The primary objective of every company generally relates to increasing the profit and growth of the company, however the way it is achieved differs from scenario to scenario. In product recovery, these opportunities come in the form of lowering procurement cost, establishing necessary assessment and inspection facilities, reducing the disposal cost, etc.

Figure 3 shows the strategic view of a typical product recovery company using a UML object diagram. The top level goal for the company is to increase market share, which is a common goal for any business. However, different businesses will adopt different routes and hence will have different "sub-goals" to achieve it. As discussed earlier, procurement of used product is a major activity for product recovery. Lowering the cost associated with procurement will significantly lead to high profits.

The customers for a product recovery company could be an OEM (which has contracted the company for recovery of its product returns) or an end user. In the case of product recovery, one of the things that need to be done is to campaign about the reuse and remanufacturing of product and make potential customers aware of the fact that these refurbished products are cheaper and more environment friendly. Apart from the individual end user, in some cases high volume consumers turn to be the perfect client for recovered product as they act as the source of used products as well as a destination for remanufactured products. On the other hand, while campaigning to attract new customers, it is necessary to maintain the satisfaction level of existing customers by quality assurance and timely delivery.

It can be noticed in figure 3 that some of the sub-goals are marked 'complete' while some are marked 'incomplete'. During the revisions, the state of the system changes according to situations and should help the managers understand the progress towards achieving particular goals. It should be noted that the enterprise under consideration is working in a collaborative environment, and therefore the interpretation of the goals can be different in various cases. If the company is an independent recovery company, it will aim to satisfy the end user, however a contract recovery company will try to meet the OEM's standards. In a collaborative environment, the performance of the company is quite influenced by the performance of other collaborators. So the enterprise needs to be aware of its collaborators' performance. This is shown in the next view.

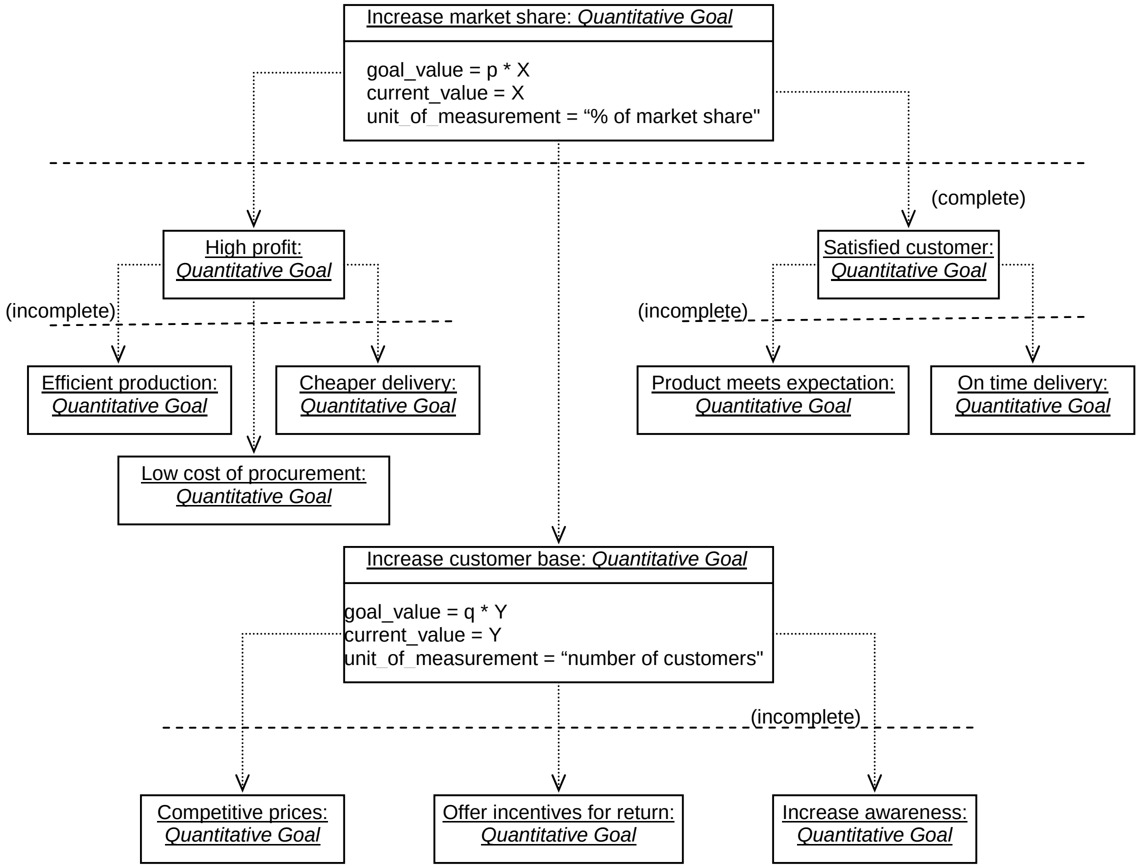

Figure 3: Strategic view of the product recovery enterprise

Function View

The business functions or activities which are essential to the operation of the enterprise are shown by the *function view*. The function view is primarily for information gathering and formulation. At the later stages of designing, when more detailed information is available, it can be replaced by a *business process view*.

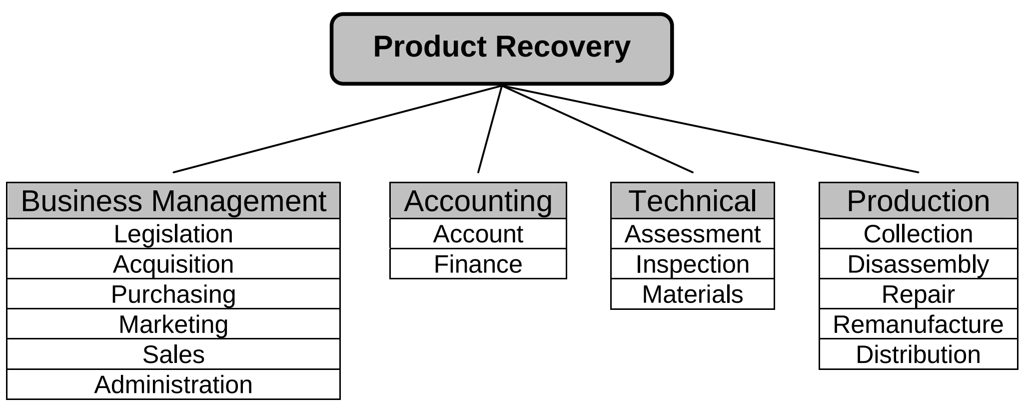

Figure 4: Organizational view of the product recovery enterprise

To better understand the requirements of the function view, it is useful to include an *organizational view*. This allows the designer to define the main functions and processes step by step. Later these can be refined and more details can be added when necessary. Figure 4 presents the organizational view of the product recovery company. Discussion of departmental responsibilities through the organizational view may facilitate the production of the function view. For example, one of the major influences in a product recovery company's strategy is the government legislation. The management needs to keep an eye on the changes on the legislation so that its products comply with the standards. On the other hand, the company must make use of any business opportunities arising due to such changes. Inclusion of a legal or legislation function in the organisational view will ensure that these considerations are taken care of when generating the function view.

Unlike a traditional manufacturing company, there are two distinct types of raw-materials sources, the major one being the user with used products at their end of life; hence the acquisition function is needed in the organisational view. In addition remanufacturing processes need other consumables or critical components which need to be purchased. In the case of a traditional company, the acquisition/purchasing and marketing/sales functions will always belong to different departments. However, in a product recovery company, they can stay with the same management group as in this context, the production is more driven by availability of used products than by the demand in the market. Administration is a common function for any department, however in figure 4 it has been included only in the business management function where it represents administering the whole company rather than the department itself.

After defining the top level functions within the departments in the organisational view, the functional view can be developed by the additional refinement of these functions. Figure 5 shows one such refinement. Modelling becomes useful when it enables the behaviour and performance capability of the factory design to be analysed and assessed before undertaking the implementation. The organisational and functional views described above help building an essential comprehension of the business elements and structure of the enterprise.

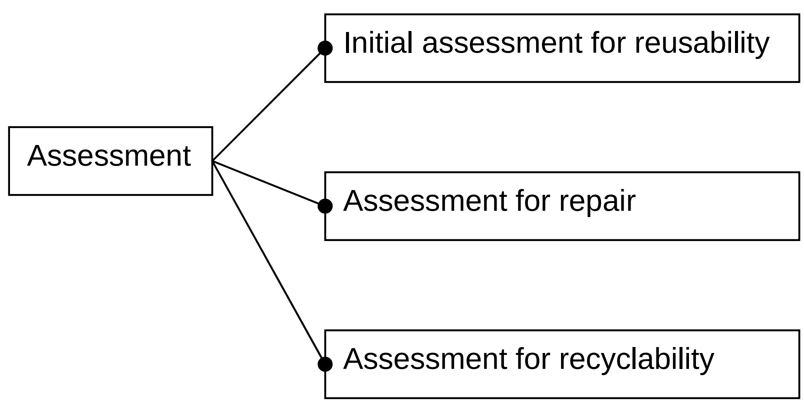

Figure 5: First phase of refinement of business functions

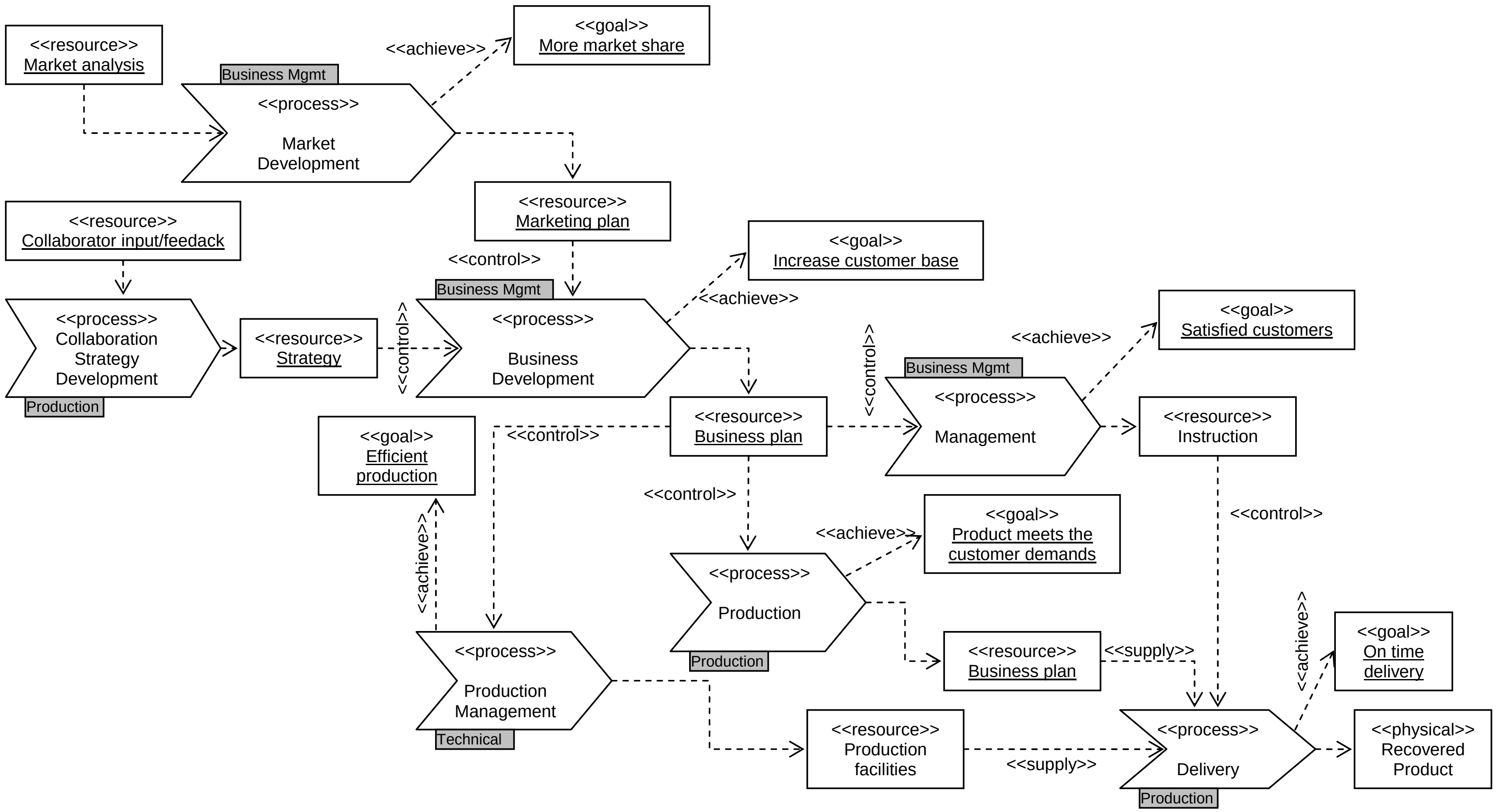

Figure 6: Business process view of the product recovery enterprise

The understanding of the business elements and enterprise structure leads to the understanding of the business behaviour by the application of the business process view. Based on the goals set in the strategic view, the business processes are identified and specific information associated with them are gathered. Figure 6 shows the business process view using UML activity diagram with the involvement of departments of the enterprise in it. It shows the activities, what it is controlled by, its goal and its output. The small grey boxes indicate the departments the activity belongs to. When the business process view is taken, the order of processes or activities so that the model captures the way in which the processes are linked. Once the structure of one or more business processes has been achieved, the relationship between the business functions and business processes can be examined. Business processes may be refined and details may be added as and when required.

Informational View

Before moving to performance view, an additional view is presented to show the informational viewpoint of physical objects and entities in the system. UML object diagrams are used to show the information related to physical objects and entities. Figure 7 shows the details of different objects in the system. For example, the information regarding the product include its type, condition, serial etc. Product pr1 belongs to product class ABC123 and it is an electronic component. Its condition is the numeric value 2, which could mean it is in reusable, recyclable or disposable condition. If recovery is carried out, it will need parts s039 and c120. It also contains the serial number given by the OEM at the time of production, which actually can help in getting the technical details about it from the database. This information is passed across the enterprise when needed and used at different places according to the situation. Before discussing the flow of information in and across the enterprises, performance view is presented in next sub section.

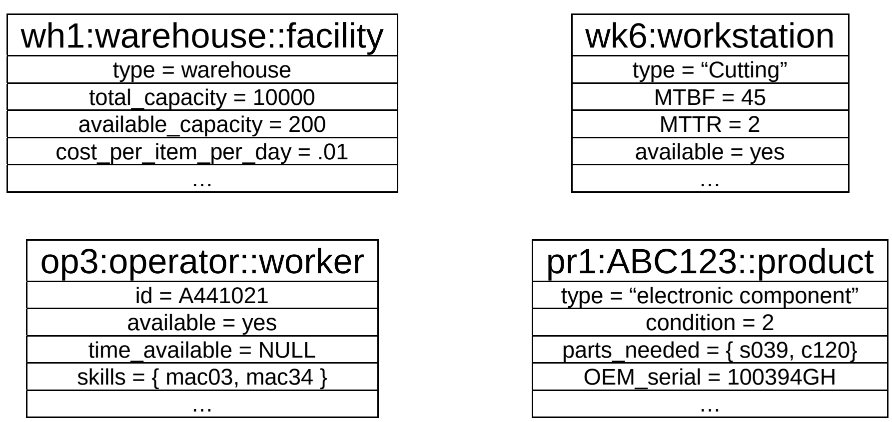

Figure 7: UML object diagrams used to show the entity/object information

Performance View

Once a sequence of processes and the resources they use have been identified, it is possible to look at the information from a *performance view*. The performance view helps the managers and designers to examine if the proposed enterprise can perform to its expectations and hence it provides them with valuable feedback at various stages of the design. There are several methods for performance measurement. The performance view proposed in this research uses two approaches for performance evaluation. Static evaluation uses performance metrics, like lead time, throughput or costs etc. On the other hand, dynamic evaluation uses simulation technology enabling ‘what-if’ experiments to be carried out. Dynamic evaluation gives the designer a better insight of how the proposed enterprise will work. This paper focuses on the assessment of dynamic performance of the system with the aid of simulation models. Following the simulation experiments, the designs can be refined further by revisiting the previous views.

For building the performance view, detailed information related to processes and resources is needed. A detailed simulation model will need data related to machine breakdown history, maintenance requirements, operational rules, etc. With the help of an informational view, the behaviour of real systems can be mimicked by building the performance view and using them to understand the utilization of different resources in the system and help making decision about capacity etc.

Simulation models were created using the Arena software (Kelton, Sadowski, & Sadowski, 1998) and the information required to build the simulation model was taken from the enterprise model. The simulation experiments were planned with the objective of deciding the location and capacities of different facilities of the system. It is a macro level design problem so the majority of the simulation decisions at micro level were based on assumptions and probability.

Informational Flow

Figure 8 shows the flow of information in typical product recovery activities. If all the activities are performed by one actor, the information flow will be simple to manage and access. However, the product recovery industry essentially works in a networked and collaborative environment, which complicates the situation further. In such scenarios, the enterprise should be provided with easy access to the information to relevant department while maintaining confidentiality of sensitive data when dealing with its collaborators.

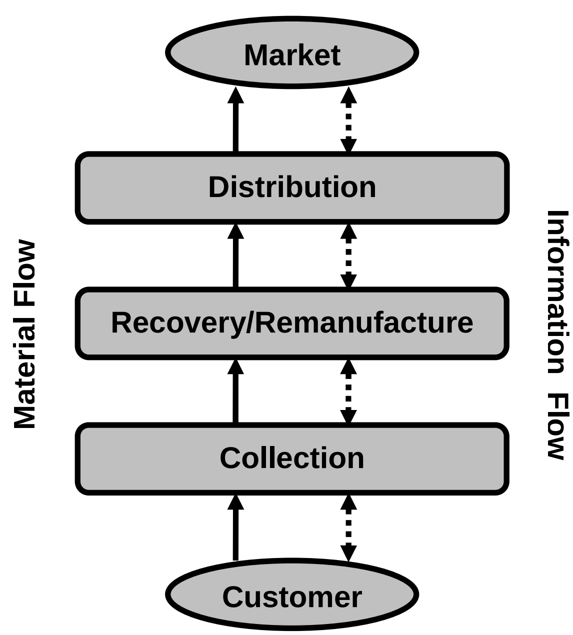

Figure 8: Material and information flow in product recovery

Figure 9 shows typical flow of information in and across two networked companies performing the same activities as those in Figure 8, but in collaboration. One of the companies is involved in independent recovery while the other is a logistics provider. So the first job of collecting the used product from the user is the responsibility of the logistics provider while rest of the production work, viz. assessment, disassembly, repair, remanufacturing, etc. are done by the independent recoverer. The business management department of both the companies handle the job of communicating with the outer world, while the other departments can contact and exchange relevant information among themselves.

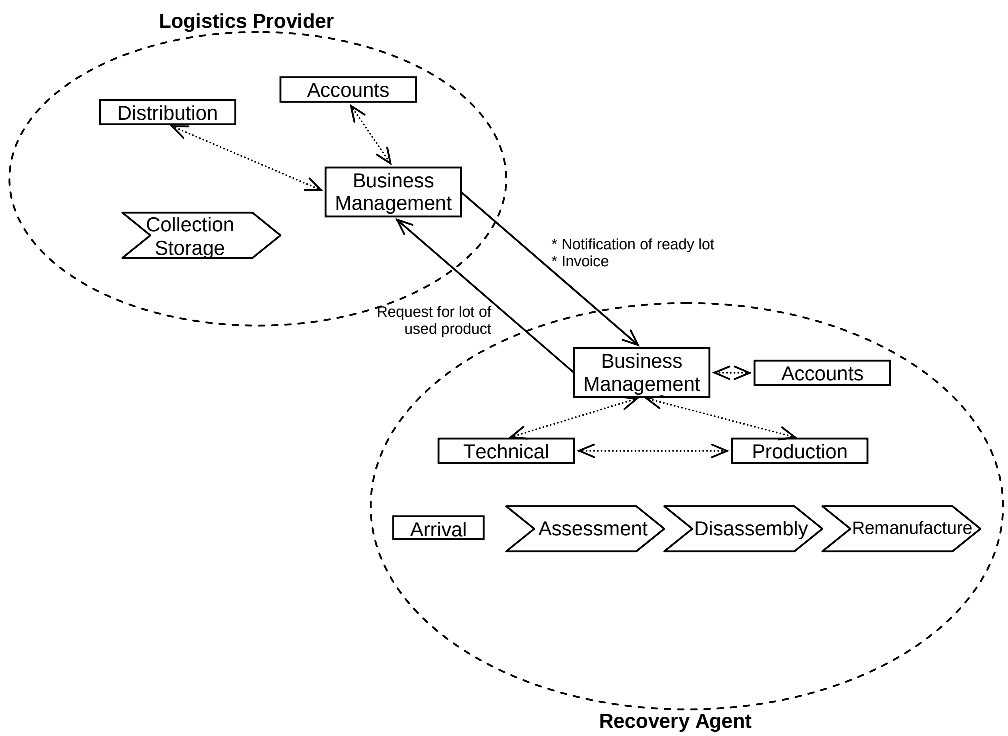

Figure 9: Typical information flow in a network of two collaborating enterprises

Based on this concept, the performance view of the proposed model can be extended to evaluate the enterprise in presence of "dummy" collaborators. Though it makes the simulation modelling part more complex, it brings the model closer to reality and hence results in higher confidence level of the evaluation. The authors are in process of building distributed simulations for networked enterprises. In order to achieve this, Arena has been used in conjunction with Visual Basic, and the communication between different simulations has been carried out though an agent based system.

Conclusion

In order to survive in the ever changing recovery market, small and medium enterprises involved in product recovery must be ready to redesign and adapt to the requirements of new products in an effective and competitive manner. This paper presents an information centric formal model for product recovery enterprises. The aim of the model is to aid the designers with modelling and evaluation tools to enable the progressive design of the enterprise. A variety of views of the model and their functionality have been discussed. The model can be evaluated using one of the viewpoints designed for this purpose. The views are presented in unified modelling language, which is an industry standard. The model is generic in nature and takes care of the networked and collaborative nature of the industry.

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