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Collaborative Workflow Modelling Based on Activity Diagrams, Coloured Petri-nets and System Dynamics

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Thesis Summary

This thesis addresses one of the most challenging issues in today's dynamic, complex and fast changing business environment: Collaborative Workflow Management. It provides methods on how to model complex, large-scale collaborative business processes, inter-dependent relationships between the organisations, and heterogeneous collaboration entities, to help re-engineer IT-based Workflow Management Systems, and to enable inter-operability and information sharing to overcome traditional closed-wall-based legacy systems which cannot easily work together and cause lower productivity.

This thesis defines different types of collaborative workflows, namely: intra-organisation collaborative workflow, inter-organisation collaborative workflow, and heterogeneous organisation collaborative workflow, and the challenges each of these are facing. The contribution of this thesis is that it developed several techniques to support collaborative workflow modelling, design, implementation and management of large-scale, complex collaborative environments including Extended Activities Diagrams, Coloured Petri-nets, System Dynamics Modelling, Managerial Administrative Operational (MAO) Workflow Model, Service Oriented and Self-organisation Workflow Management.

In order to provide proof of concept, the thesis chose the transport logistics industry as a test-bed. The practical issues were drawn from two industry collaborators, namely: Seapower Resource International on the Central Coast, NSW, and a virtual collaborative logistics consortium partnership and Fremantle Port Vehicle Congestion Management. The long overdue core issue has been the provision of seamless information communication and real-time information sharing between big or small-medium logistics enterprises for productivity management, and the underlying challenge has been the provision of a virtual infrastructure that virtually integrate the partners with effective IT-based workflow management, so that it can effectively facilitate the coordination, and cooperation as well as real-time tracking and tracing of goods and services across the supply chain in the regions and beyond borders in collaborative partnership businesses. This thesis also laid out the challenges of existing work and possible future solutions.

Statement of Authorship

Except where reference is made in the text of the thesis, this thesis contains no material published elsewhere or extracted in whole or in part from a thesis submitted for the award of any other degree or diploma

No other person's work has been used without acknowledgment in the main text of the thesis.

This thesis has not been submitted for the award of any degree or diploma in any other tertiary institution.

Signed: ______________________________

Leo Pudhota

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List of Publications

1. Pudhota L, Dong H., Chang E., Collaborative Workflow and Bullwhip effect on SMEs", to appear in Proceedings of IEEE International Conference on Industrial Informatics 2013, Canada.

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6. Pudhota L, Chang E "Coloured Petrinet For Flexible Business Workflow Modelling", INDIN05, Perth, Western Australia, 10-12 August 2005

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10. Pudhota L, Chang E "Service Oriented Model Driven Architecture For Dynamic Workflow Changes", ICEIS, WSMAI, May 2005, Miami USA.

11. Pudhota L, Chang E "Workflow change management through Synchronisation", IMB March 2005 Taipei, Taiwan.

12. Pudhota L, Chang E "collaborative workflow management for logistics consortium", ICEIS April 2004, Porto, Portugal.

13. Pudhota L, Chang E "Modelling the Dynamic Relationships between Workflow Components", ICEIS April 2004, Porto, Portugal.

14. Pudhota L, Chang E Venable J "E- Business technology adaptation through workflow mining", MSV June 2004, Las Vegas, Nevada, USA.

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17. Chang E, Pudhota L "Engineering Process in Software Maintenance", IEEE-ICNP Paris 2003 France

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Chapter 1 - Motivation

1.1 INTRODUCTION

In this thesis, we develop advanced techniques for modelling the large-scale collaborative workflows in today's dynamic business environment. This chapter starts by describing why we need collaborative workflow, why modelling, what types of collaborative workflow models already exist, what the key issues are in modelling collaborative workflows, and what this research is intended to achieve. At the end of this chapter, we provide an overview of the aim of the thesis, the significance of this research and the plan of this thesis.

1.2 THE DYNAMIC CHANGING WORLD REQUIRES A COLLABORATIVE BUSINESS MODEL

The only constant in our modern age is Change (Sterman, J. 2000) and human-invented technology is one of the root causes of this change, and is a catalyst for social, economic and environmental changes (Chang, E., Pudhota L. 2012). Businesses often have to reinvent themselves each time the technological tsunami hits the socio-economic landscape. Policy makers struggle to address the issues resulting from the dynamic changes in the surrounding environments and sometimes the best effort in policy formation makes the operation and services worse. Every business today has to undertake digital transformations (Inglesby T, Patricia & Yatchisin, George (1998). As humans accelerate the development of advanced technologies, business faces a fast-changing environment where the pressures and demands for efficiency, profitability, quality, price and innovation continue to increase. Those previously self-contained closed-wall business models and operations become completely irrelevant (Pudhota L. Chang, E., 2013).

Today's business model requires global participation as well as being adaptive and collaborative to optimize the individual organisation's production, services and enterprise resources. Organisations must be prepared to deploy the collaborative intra-, inter- and heterogeneous organisational environment, optimizing skills across the various divisions, boards, and alliances to create a portfolio of collaborative businesses not only for their own benefit and profit but also to offer a better product and service to meet the evolving needs of the world.

The transition from previous closed-wall business models to an open, collaborative, global participation business model requires visionary business leaders and social-minded policy makers who can develop critical short-term and long-term strategies by utilising cutting edge networked economic systems and environments and encouraging cooperation, competition and innovation which can turn the challenges to opportunities (Pudhota L. Chang, E., 2013).

1.3 TRADITIONAL BUSINESS MODELS AND PRINCIPLES

1.3.1 Traditional Business Model

The day-to-day businesses we see around us from news agencies to gas stations can be considered as being traditional businesses. The traditional business models are closed, self-contained, productivity- and profit-driven operations and services. They are usually seen as being time- and money-driven entities (Chang, E., Pudhota L. Martin G. 2012).

1.3.2 **Traditional Business Principles**

Traditional business principles, generally speaking, have:

- Two primary fundamentals: productivity and profit. These can be translated as ‘time’ and ‘money’.

- CRM (Customer Relationship Management) and ERP (Enterprise Resource Planning), along with sales and marketing components, as part of core business operations for medium to large businesses/corporations whether private or government.

- Secondary principles, largely for medium to large corporations (private or government); they include enterprise knowledge management (KM), key performance index (KPI) and business intelligence (BI).

Modern technology and the digital economy drive businesses to global levels. On the positive side, they open up endless new opportunities and possibilities to increase sales and marketing, empower businesses by sharing resources, product development and production opportunities, along with advancing customer services, all of which enable a business to extend beyond its own original operation. On the negative side, collaborative business implemented by collaborative workflow requires change of traditional business models, thinking, mindset, mode of operation, and business processes. It directly impacts on all of the above principles. The adaptation of a new open and collaborative business model has been slow, especially in small-medium enterprises (SMEs).

1.4 COLLABORATIVE BUSINESS MODELS AND PRINCIPLES

1.4.1 Collaborative Business Model

The Collaborative Business Model emerged as a mainstream new business model in the 21st century due to the availability of strong technology infrastructures which made global business possible. Collaborative Business Models are businesses and/or alliances that utilise advanced ICT with integration of intra- and inter-organisational services and products for global customer services. Such collaborative businesses are transformed from those original closed-wall business operations to a new, open collaborative partnership, creating new business values by making connections. This requires especially small-medium enterprises (SMEs), which have to reconfigure their business models and operations, to build new capabilities that enable them to join the global business world, global customer services, and global business partnerships.

1.4.2 Collaborative Business Principles

Collaborative businesses inherit all the traditional business principles mentioned above. In addition, they extend the business models to include the following activities:

- Collaboration with competitors for large-scale operations;
- Sharing information, resources and infrastructure with the partners and competitors for large-scale services;
- Cooperation in production, sales and marketing between the partners and competitors for large-scale social and economic demands;

- Implementation of new collaboration policies and procedures through extended ERP (Enterprise Resource Planning), Ex-CRM (Customer Relationship Management) and BI (Business Intelligence); and

- Migrating to collaborative workflow modelling through interoperability, one-stop shop and information transparency across the partners, the community, the consortium, and alliances.

1.5 ENABLING TECHNOLOGIES UNDERPIN THE COLLABORATIVE BUSINESS

Due to the transition of business towards globalization, one of the key success factors is having a strong ICT infrastructure to support the distributed large-scale operations within the enterprise and between the partners in the integrated intra-, inter- and heterogeneous-organisations' environment. The advanced ICT systems, including software and hardware, play a critical role in the fundamental cooperation, collaboration, governance, large-scale products' and services' support, marketing and sales, as well as large-scale resource management.

1.6 WORKFLOW MANAGEMENT UNDERPINS THE ENABLING TECHNOLOGIES

Underlying the enabling technologies or advanced ICT (Information, Communication and Technologies) in global business is the seamless collaborative workflow management which ties intra-, inter- and heterogeneous-partnerships together in order to attain seamless resource, information, product and service sharing, exchange and monitoring. It is a primary foundation for business growth within and between the partnerships.

Workflow and collaborative workflow are not new concepts. However, due to the dynamic and complex nature of business partnerships and large-scale operations, there has been no blue sky solution for today's ever-changing business and economic environment. One of the solutions has been to model the collaborative workflow environment to provide a conceptual understanding of the complex collaboration between the processes, services, divisions, and enterprises in the intra-, inter- and hetero-organisational environment.

Modelling the workflow enables us to understand the structure and dynamics of a complex collaborative environment. Through rigorous scientific approaches including formal system dynamics and complexity theory, we can use them as input for large-scale collaborative business modelling and management tools enabling the senior executives to design more effective policies, strategies and processes in order for collaborative business to succeed. Additionally, modelling the complex collaborative workflow will help us to better and more quickly understand the problem domain and to thoroughly comprehend the issues, so as to build better cooperation in collaborative structures that correspond with the competition and enabling them to meet business, customer and social needs.

1.7 TYPES OF COLLABORATIVE WORKFLOW MODELS

As mentioned earlier, workflow and collaborative workflow are not new. 'Workflow' has been around for a long time and with the advent of the Internet, collaborative workflow has also become prominent. Many types of collaborative workflow models and techniques have been developed in the previous two decades. We note that most of the collaborative workflow models in the literature fit well with intra- and inter-organisation collaborative environments, and these are summarized below.

1.7.1 Intra-Organisation Collaborative Workflow

This collaborative workflow represents the collaboration within an organisation. There are successful technologies such as well-known data flow approaches, unified modelling languages, and object-oriented conceptual modelling etc. available to facilitate intra-organisation collaboration. This type of workflow management can be well-planned, designed and implemented if there is one policy, one portal, and one set of organisational-defined business operation rules within and throughout the organisation. The collaborative entities are dependent on each other to succeed in business or profit making, and each party is autonomous. We name this 'Intra-Organisation Collaborative Workflow'.

A conceptual representation of Intra-Organisation Collaborative Workflow is shown in Figure 1.1.

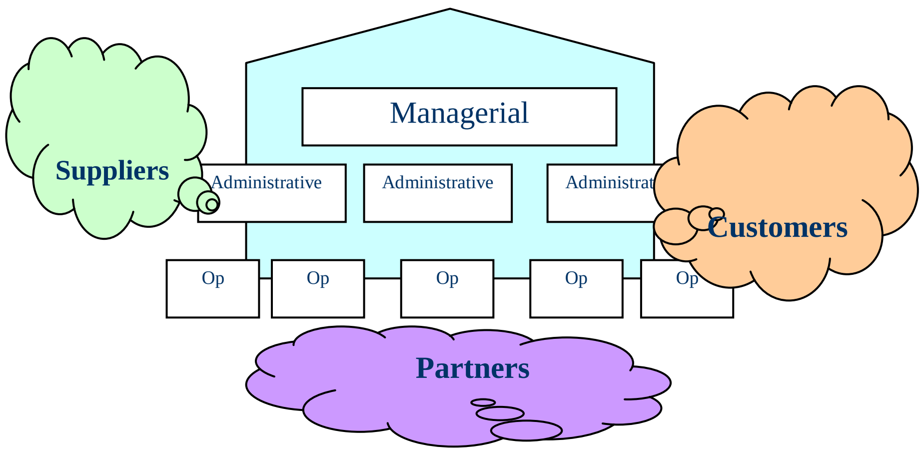


Figure 1-1: Conceptual View of Intra-Organisation Collaborative Workflow

1.7.2 **Inter-Organisation Collaborative Workflow**

With Inter-Organisation Collaborative Workflow, work is carried out between the organisations. Each organisation is a self-organised, self-contained business entity, and is often from one vertical industry such as an airline alliance or cold-store warehouse chain, or from horizontal industries such as logistics and supply chains. However, between these organisations, there must be a pre-defined commercial arrangement, usually known as a Service Level Agreement (SLA), which includes a financial arrangement between the partners. This SLA may include confirmation regarding profit-sharing arrangements, commission, incentives or penalties and fines if breach of the agreement occurs. This collaborative partnership environment has agreed policies, agreed portal arrangements, and agreed rules within and between the partnership and alliances along with the collaborative parties or entities having partial dependency and partial independency. This type of collaborative workflow is named Inter-Organisation Collaborative Workflow.

A conceptual representation of Inter-organisation collaborative workflow is shown in Figure 1.2.

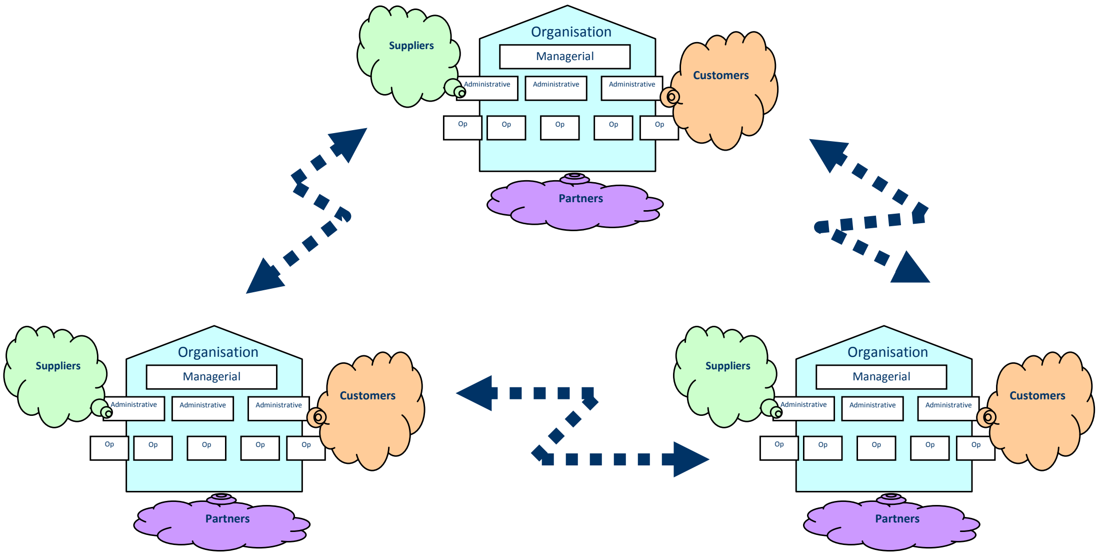


Figure 1-2: Conceptual View of Inter-Organisation Collaborative Workflow

1.7.3 **Heterogeneous-Organisation Collaborative Workflow**

In this instance, collaborative workflow is carried out between the heterogeneous organisations or parties with a mixture of vertical industries collaborating or horizontal industries collaborating, that need to work together and interact with each other to achieve business objectives under a commonly understood business framework without any service level agreement or any commercial arrangement. Each party is a self-organised, self-contained business entity. As there is no direct financial agreement or financial transaction between any parties, and no defined profit-sharing or agreement on customer-sharing despite the fact that they need each other to get a project underway or completed, the collaborating parties have an inter-dependent relationship.

An inter-dependent relationship is distinguishable from a fully or partially dependent relationship. An inter-dependent relationship in a Heterogeneous Organisation Collaboration means that all the interdependent enterprises in the collaborative environment are mutually and physically related, sharing a responsibility and a common set of principles, and each party in the relationship cannot function or survive independently of the other(s). In this interdependent relationship, all parties are economically, ecologically and morally self-reliant, while at the same time responsible for each other. The unique feature of this type of relationship is that it is a self-organised, demand-driven, flexible arrangement, and that a party may join or withdraw from the relationship at any given time. This is similar to a peer-to-peer communication environment or to ecosystems. Each party or agent is autonomous and participates and conserves the environment for its own benefit and profit.

An example of a heterogeneous organisation collaboration is container port operations which include government, semi-government, public and private parties, and small and large enterprises that have to work together to make their own profit and at the same time achieve benefits for the wider community. Between the partners there is no financial arrangement; each party or partners is not paid by other parties or partners but rather by their own customers. This means that each party has to provide its own service and gest paid by its own customers.

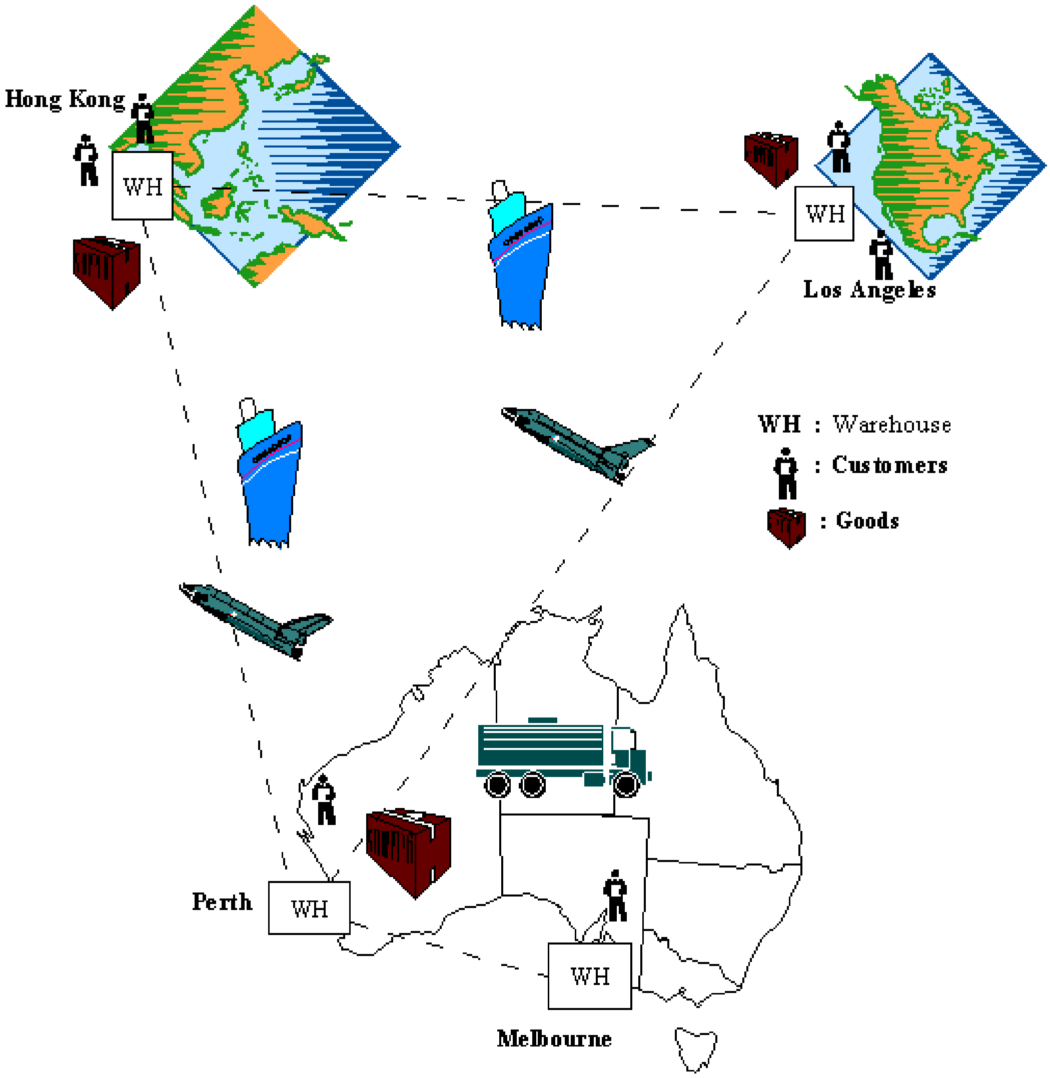


Figure 1-3: Conceptual View of a Heterogeneous-Organisation Workflow

We found that this type of workflow has never been previously modelled in the literature. This type of collaborative workflow is often seen in mixed horizontal and vertical industries' collaborations. These types of workflows are complex to model, to understand, and to manage as they all have their own policies, portals, systems, and business rules. Therefore, it is difficult to find neutral policies or procedures that suit all parties. These types of policies, procedures and rules for such a collaborative community need to be established over and above each organisation's own policies and rules. If there is no financial engagement or incentives, there is a lack of motivation to develop a mutually agreeable collaborative model and it is therefore hard to satisfy all parties' needs.

This community-based, heterogeneous, non-commercial organisation collaborative workflow may be shortened to ‘Community-based Hetero-Organisation Collaborative Workflow’. A conceptual representation of such a workflow is depicted in Figure 1.3 above. A port operation is a typical example of a heterogeneous collaborative workflow environment as shown in Figure 1.4 below.

Figure 1-4: Heterogeneous-Organisation Workflow Environments in Ports

Port Operation is a very complex collaborative business environment. In Australia’s WA port, the heterogeneous organization collaboration environment consists of 162 registered individual business entities (transport operators) who operate at the port each day, together with 70+ independent port operators who work at the port and include stevedores, empty container yard operators, customs officers, X-Ray operators, wharf front terminal operators, container train operators etc. Five per cent are large enterprises (namely two stevedore companies, considered monopolies) and 95% are so-called SMEs which include road carriers or container transport operators. Together they currently move containers, about 200,000 TEU (containers)annually. However, if they cooperate efficiently, they could shift 1 million TEU per year as indicated by each operator, large or small, on-port operators or road carriers (Chang, Pudhota 2012).

1.8 CHALLENGES OF COLLABORATIVE WORKFLOW MODELLING

In this section, we present the challenges in modelling the collaborative workflow and the technical challenges in using the conceptual techniques and tools. We also provide a brief outline of existing approaches and methods and show how these methods have not been updated or extended to model the emerging issues in collaborative workflow.

1.8.1 Existing Collaborative Workflow Methods

Workflow methodologies and techniques today are challenged by the need to address the workflow issues in the dynamic and changing business, social and economic environments. Furthermore, there are no techniques or methodologies available to model collaborative workflow in Heterogeneous Organisation Collaborative environments. In this thesis, we first develop advanced approaches to model collaborative workflow for intra- and inter-collaborative workflows which can be used for the collaborative workflow in a dynamic business environment. We then present a modelling approach to community-based heterogeneous organisation collaborative workflow that is able to capture the inter-dependent dynamic collaborative workflow that can address the complexity of the community-based heterogeneous organisation partnership's collaboration and management.

1.8.2 Major Challenges in Collaborative Workflow Modelling

Through our study, we have identified five major challenges in modelling the collaborative workflow and the existing methods and techniques have yet to address these challenges. We map these challenges to each type of workflow we have presented in the section above, thereby clarifying the work that has not yet been done.

The challenges are due to the complexity of the collaborative workflow environment.

1. Collaborative workflow modelling is challenged by the 'real-time dependency relationships'. In a highly competitive business environment, we often see that the time frame is unchanged but the business activities are increased due to changes in expectations of quality and frequency . This often causes workflow breakdown and it introduces new financial and human resource issues within the collaborative community which are difficult to model.

2. Collaborative workflow modelling is challenged by today's 'Information Technology Infrastructure relationships'. The Information Technology (IT) infrastructure is constantly evolving and being upgraded. The core part of business IT is the 'workflow software'. Traditional workflow systems have been treated as 'nice to have' but 'not a solution'. Therefore, some of the workflow software available deals with only one part of the workflow, or one part of the business process or one party in the workflow (i.e. it helps only one party or one organisation). It was not built as a community-based collaborative workflow solution for the entire community. Most of the time, this traditional workflow software creates problems within the community. It is hard to replace but a new solution is needed.

3. Collaborative workflow modelling is challenged by the 'financial engagement relationships'. If a community consists of many small to medium enterprises (SMEs) as well as several large enterprises, and there is a mixture of public and private sectors, one of the key collaborative functions is to define a shared vision, and agreed policies or procedures which satisfy all heterogeneous organisations. We often see that the vision is not appreciated by all parties as it needs expert input, financial support and efforts from all parties to develop and to advocate the vision and polices. Who is going to pay for this? Who should pay proportionately more or less? Should larger or more profitable organisations pay more? What is a fair charge if an organisation pays

more for its annual contribution to the government and society, or through tax and through goods and services sales? Who is responsible for building the shared strategy and common policy? How can one promote the community-based polices and visionary ideas? Who pays for such effort? Without answers to such questions, collaboration in such a complex environment will not be sustainable.

4. Collaborative workflow is challenged by the concept of ‘resource sharing relationships’, as this contradicts the traditional business model where business is usually concerned with its own profits and benefits, and ‘sharing’ is absolutely excluded from the traditional business model. ‘Sharing’ may include space sharing, common gate sharing, human labour sharing, information and data sharing, network sharing and the like. With a 'community’ of parties, a collaborative organisation has to ‘share’. This is a break from the foundation of the traditional business model. If the collaboration does not deal with ‘sharing’ as its principal, there will be no bi-directional profit, nor bi-direction benefit, and the collaboration will not be sustainable.

5. Collaborative workflow is hindered by the concept of the ‘Community relationships’. Community also implies that one has to ‘consider others’. It is not difficult to agree that ‘productivity’ is one of the key objectives; however, if productivity is very poor across the board, who is responsible and who is to blame for the productivity levels? Traditional business owners usually run only a ‘self-centred business’, and do not ‘consider others’. It is not a business process issue or management issue. It requires a breakthrough thinking and brainstorming of the fundamental model for collaborative business in the 21st century.

1.8.3 Modelling as a Solution to Complex Workflow Understanding

Once we understand the challenges, the next step is to develop appropriate strategies to meet the challenges through renewed IT and policies and as procedures. Nowadays, we cannot adjust only one component as all components are interconnected. We are facing the reality that everything is connected to everything else. Therefore, we need visionary leadership and a socially-oriented policy-maker to develop short- and long-term strategies to avoid any collaborative resistance.

The modelling here is to help our leaders and policy makers to understand the complex business and collaborative workflow environments in which we are currently operating, so they are better able to make operational decisions regarding policy. Because many leaders and policy-makers do not live in similarly complex environments, it is difficult to visualize the complex nature of such environments and the causes of these complexities. We need to help them find tools and methods that can be utilised to comprehend the problems faster. This will also help in the development of strategies and policies that will sustain the entire enterprise.

'Modelling' is one such tool or method that senior executives can use to help them to better and more quickly understand the complex world in which they operate. It will also assist them to initiate polices for the sustainability of the entire enterprise.

Modelling requires an inter-disciplinary approach of science, engineering, social science, behavioural science, cognitive science, and economics. It is grounded in the theory of non-liner dynamics, chaos and randomness coupled with scientific reasoning skills.

In this thesis, we focus on developing and enriching the field of collaborative workflow modelling techniques and tools which can enhance the understanding of the dynamic, complex environment that business operate in on a day to day basis. Such modelling provides tools so that we can avoid, once again, world economic crises, the consequences of which have been inherited today.

1.9 WORKFLOW MODELLING

In this section, we give an overview of the technical challenges that the author is facing including how the modelling can address different types of collaborative workflow, and how to make a new innovation to the existing workflow modelling approaches so that we can overcome the challenges of collaborative workflow modelling that will facilitate the development of a collaborative business system.

1.9.1 Technical Challenges

Collaboration is a concept now permeating all businesses in the networked economy. It impacts on the development of the social, and economic environment of all large and small businesses. In order to facilitate the business collaboration through partial automation, or fully automated processes, IT experts led by Silicon Valley, such as IBM, Oracle, Microsoft etc. together with many domain specific software industries, such as Supply-Chain Software, or One-Stop etc., developed many systems known as "Workflow Management Systems" (see previous section 1.5 "Enabling Technologies underpin the Collaborative Business"). In order to develop such systems, one has to model the workflow and workflow environment in a real-world scenario and then translate this into a software package for workflow automation. In the transportation industry, most shipments, it does not matter whether what is being shifted is a book, or a container, or a tank of milk, or climate-controlled cargos, are now largely automatically controlled by an IT system, known as a Workflow Management System.

The greater the development of IT systems and IT infrastructure, the more opportunities there are for businesses to collaborate to reap more benefits and profit. Today's collaborative workflow is much more complex than ever. As described in the previous section 1.7 "Types of Collaborative workflow models", we see that successful intra-, inter, and heterogeneous organization collaboration are empowered by strong IT systems and infrastructure. Section 1.6 illustrated how workflow modelling underpins the enabling technologies, and the objectives of the thesis are to address this technical challenge.

1.9.2 **Technical Challenges with Different Type of Collaborative Workflow**

Below, we map the collaborative workflow types to the challenges. We indicate the challenges facing each type of collaborative workflow with ‘x’; these are the challenges faced technically and methodologically when modelling and implementing the collaborative workflow.

Table 1-1: Map of Collaborative Workflow Types against Challenges

Collaborative Workflow Type / Complexity	Intra-Organisation Collaborative workflow	Inter-Organisation Collaborative workflow	Hetero-Organisation Collaborative workflow
Issue 1: Real-Time dependency relationships	x	x	x
Issue 2: IT infrastructure relationships	x	x	x
Issue 3: Financial engagement relationships		x	x
Issue 4: Resource-sharing relationships			x
Issue 5: Community relationships			x

x: denote it is a challenge

1.9.3 **Technical Challenges with Existing Proposed Approaches**

Modelling is a conceptual view tool which helps us to understand the large and complex system and environments by breaking them into more understandable, simpler subsystems and simplified environments.

The technical areas of traditional workflow modelling are:

- Workflow activities, events and actions;

- Business processes;
- Asynchronous and synchronous processes and parallel processes; and
- Flow of interactions.

Modern workflow modelling is required to address:

- Inter-dependent relationships;
- Continuing emergence and evolution of the collaboration structure; and
- Large-scale and chaos in collaboration.

So far there is no method or approach for modelling the complexity of heterogeneous collaborative workflow, especially modelling the dynamics of inter-dependent relationships, the constant emerging structure of the collaborative workflow structure, and the chaos that is often created due to large-scale participation by many SMEs as well as large enterprises. Chaos brings problems and issues, hinders the business growth, creates a bottleneck and resistance in cooperation. Several case studies are presented in this thesis to illustrate the challenges facing today's businesses including both SMEs and large, multi-national corporations.

1.9.4 Technical Challenges with Large-scale and Complex Environments

In addition to the abovementioned challenges, the author is also facing challenges in addressing large-scale collaborative enterprise environments. such as how to model the "large" or "big" and "real-time" and "complexity". How to set limits and constraints? How is the IT systems and infrastructure and financial engagement between business partners is managed so that their cooperation is motivated and collaborative workflow management is achieved? How are openness, resource sharing and the community concepts to be addressed? How can the dynamism of workflow components be modelled so that when the model is changed, the workflow system can adapt to the change quickly and/or automatically? How can we capture the factors that precipitated the change in workflow? How do we know our workflow model is more dynamic? How dynamic can a workflow management system be made? How can we construct a formal method that can be applied to large-scale enterprise collaboration? Due to the time constraints, some of these questions will not be fully addressed in this thesis.

1.10 THE AIMS OF THE THESIS

Therefore, in this thesis, we have five aims, namely:

1. To clearly distinguish different concepts used in the literature and to provide a comprehensive body of knowledge for the collaborative workflow.

2. To present a state-of-the-art review of different types of workflow modelling techniques, systems and management approaches.

3. To clearly define the types of collaborative workflows and the key challenges within each type of collaborative workflow.

4. To develop advanced modelling techniques for collaborative workflow in a dynamic, large-scale, complex business environment, which includes modelling the intra-, inter- and heterogeneous organisation workflow.

5. To provide case studies and simulation as proof of concepts and to evaluate the techniques proposed.

1.11 SIGNIFICANCE OF THE RESEARCH

The conceptual view of collaborative workflow helps in planning, designing and implementing a dynamic business model and dealing with changes. The significance of this research achieves the following:

- An enhanced approach for intra-organisation collaborative workflow modelling;

- An enhanced approach for inter-organisation collaborative workflow modelling;
- A modelling approach to model the dynamic aspects of workflow in heterogeneous collaborative workflow environments;
- Identifying the key factors that underline the large-scale collaborative workflow model;
- Adoption of a dynamic system framework to large-scale, complex workflow modelling in heterogeneous organisation environments; and
- Evaluation through case studies and simulation results.

The outcomes of the study that benefit industry are:

- A comprehensive body of knowledge and ontology for workflow and collaborative workflow;
- A clear understanding of various aspects and issues in the large-scale collaborative workflow environment;
- An increase in productivity, efficiency and return on investment;
- An improved understanding of the complex collaborative process; and
- Proposed enhanced techniques for accuracy, timeliness and completion of collaborative business modelling that is ready to use in a real-world setting and can be used as a blueprint for the development or re-engineering of any workflow systems.

1.12 PLAN OF THE THESIS

This thesis is organised in line with the proposed thesis aims and comprises the following chapters:

Chapter 1: Introduction and illustration of the motivation of this research

Chapter 2: Literature survey of current modelling techniques

Chapter 3: Problem definition proposal of the solution

Chapter 4: Body of knowledge for workflow and collaborative workflow

Chapter 5: Intra-organisation collaborative workflow modelling through extended activity diagrams

Chapter 6: MAO model based on intra-organisation workflow management

Chapter 7: Inter-organisation workflow modelling through coloured Petri-nets

Chapter 8: Service oriented inter-organisation workflow management

Chapter 9: Heterogeneous-organisation collaborative workflow modelling

Chapter 10: System dynamics for heterogeneous-organisation collaborative workflow modelling and management

Chapter 11: Recapitulation and future work

The structure of this thesis will facilitate the development of a workflow modelling method that is capable of dealing with large-scale and complex systems. As described above, many methodologies have been utilised to develop a workflow model. In this thesis, we will develop an enhanced methodology for dynamic workflow modelling.

1.13 CONCLUSION

This research aims to develop a modelling approach for dynamic business environments that will enable managers and policy makers to learn and understand the complex collaborative workflow environments, so that they can design a better business strategy and enable changes to be managed and integrated. In the next chapter, we provide a literature review of existing modelling techniques addressing the advances that have been made to date, their limitations, and how these technologies can be improved.

Chapter 2 - Literature Survey

2.1 INTRODUCTION

Workflow and collaborative workflow management is widely acknowledged as a core technology to support long-term business processes in heterogeneous and distributed environments (Georgakopoulos D. Hornik, M.; Sheth, A. 1995). However, conventional workflow management systems do not provide sufficient flexibility to cope with the cutting edge issues and broad range of dynamic situations that occur in today's complex collaborative workflow environments. In particular, most modelling techniques do not model the emerging issues related to the collaborative workflow such as 'real-time constraints' and system dynamics such as 'resource sharing' and the like between the collaborating parties.

2.2 EXISTING WORKFLOW MODELLING TECHNIQUES

Workflow modelling is accomplished by using various *modelling techniques* – also known as *workflow languages.* The existing workflow modelling techniques used to help modelling the workflow and dynamic aspects of workflow are:

- Petri-nets (Aalst, W.M.P. van der; Basten T.; Verbeek, H.M.W.; Verkoulen, P.A.C.; Voorhoevoe, M., 1999)
- Event-driven models, state event and action rules (Aalst, W.M.P van der; Jablonski, S., 2000)
- Unified Modelling Language (UML)
- Activity diagrams (Guntama E., Chang, E., Jayaratna N., Pudhota L., 2003)
- Sequence diagrams combined with activity diagrams

A few other examples are data processing spheres, case plans, life-cycle diagrams, process algebra, flowcharts, structure charts, business rules, speech acts, Program Evaluation and Review Technique (PERT) networks, and data flow diagrams. The various existing techniques differ in the modelling constructs they offer, their notation, and ease of use along with other aspects.

2.3 PROCESS-ORIENTED WORKFLOW MODELLING

For enterprises and organisations operating in global and complex business or public environments, an increased productivity, profitability, flexibility and quality assurance are critical factors for success (Reichert, M., Rinderle, S., Kreher, U., Dadam, P. 2000). A major precondition for this is that organisational structures and business processes are identified, analyzed and optimized continuously in the context of computer-based business process re-engineering (Hammer, M., Stanton. S. 1995). In this context, the term *business process* commonly refers to a logical unit of work relevant to an enterprise or an organisation. Examples of business processes include the processing of a bank customer's credit application, the processing of a damage claim at an insurance company, or the administration of chemotherapy to a cancer patient. More formally, a business process is a set of business *activities* and their *temporal relationships*. For example, a typical activity is to check whether an insurance holder has filled out a car damage report correctly, or the performing of an x-ray examination in a hospital. The temporal relationships specify which activities have to be processed sequentially, in parallel, or only when certain conditions hold. Business processes may also be distributed over multiple locations due to enterprise collaboration.

Traditionally, information systems have been implemented in a function- and data-centred manner (Breitbart W, Stiefel F, Kornblith A, Pannulo S. 1993), and do not have any explicit notion of business processes. This implies that users themselves have to know when a step has to be executed. In particular, the *passive* behaviour of such traditional information systems does not support any work coordination, and does not provide mechanisms for process monitoring such as generating reminders in case of deadline violations. Consequently, *process-oriented* information systems are required to *actively* provide the right data together with the right execution instructions to the right staff member at the right time.

Conventionally, such process-oriented information systems have been implemented by incorporating the process logic directly into the application programs. This means that the different application programs supporting activities of the business process invoke each other according to the process logic, and communicate bilaterally. Though this allows active operation of a business process, it has the serious disadvantage of the overall execution logic of a business process being hidden and split up within the code of the different application programs. As a consequence, tasks that go beyond the scope of a single application program cannot be supported significantly, as a higher level control component is missing. For example, if such a higher-level control component is missing, it is difficult to determine which processes are at which execution steps, which users work on which documents and so forth. Furthermore, it is nearly impossible to handle a failure such as setting a running process into a consistent state when an application program or database server crashes.

Additionally, process maintenance is difficult as any change in the process logic has to be effected by changing the code of the different application programs. For a detailed discussion of the disadvantages of passive information systems and conventional process-oriented information systems(Reichert, Rinderle, Kreher and Dadam 2000).

The workflow management systems introduced by (Georgakopoulos, Hornick, and Sheth 1995); Alonso, Agrawal, Abbadi and Mohan 1997); and Leymann and Roller 2000), strictly separate the application program code from the overall logic of a business process. This supports a broad range of tasks going beyond the scope of a single application program such as process monitoring, failure handling and load balancing by assigning execution steps to free human or machine resources. In workflow management systems, the overall process logic is explicitly represented in an executable *process* or *workflow definition.*

Such a workflow definition first consists of a *control flow* definition specifying the order in which the activities have to be executed. Secondly, it consists of a *data flow* definition specifying which data is needed as input for the activities, and which data is produced as output of the activities. Furthermore, the data flow specifies where data has to be retrieved from, or written to, and data sources such as relational databases or user interfaces. Thirdly, the workflow specifies which *workflow resources* (e.g. users, application programs, equipment) are needed for the execution of an activity. In addition to such *intra-workflow* aspects, some workflow management systems also allow aspects of *inter-workflow* to be specified which are needed for workflow cooperation. For example, an inter-workflow specification may determine when one workflow has to provide a result for another (remote) workflow, and which temporal or qualitative constraints have to be met by this result. Orthogonal to this, workflows may also be organised *hierarchically*, that is, a *sub-workflow* may be assigned to an activity which is executed when the control flow reaches this activity.

Current support for business processes usually involves either supporting the coordination aspect of usually asynchronously executed business processes by individuals or providing communication or cooperation support for groups dealing with more fluid, ill-defined processes.

Since the early 1990s, several vendors have offered general-purpose workflow management systems. However, workflow systems today are often built in the same way as traditional application systems. That is, it is intended for a specific scenario, and is not designed to cope with a rapidly changing environment. The problems with current workflow management systems include:

- The lack of real standards combined with a large volume of vendors has created a scattered landscape where customers are reluctant to invest in workflow products. The numerous workflow management systems on the market today are based on different paradigms and offer contrasting functionality.
- Most of the workflow management systems on the market today are very inflexible for running a business.

According to Kettinger, Teng and Guha 1997, design *methodology* is primarily the field of consulting firms who have developed proprietary Business Process Re-engineering (BPR) methods. Some researchers even question the need for, or possibility of, a design methodology as they see process design as an inherently creative pursuit. Simison 1994 ridicules the development of a design methodology, stating “To write a piano concert, first take an HB pencil, select a key…". Hammer and Champy (1993) state: "Re-design [of a new process] is the most nakedly creative part of the entire re-engineering process... it is not algorithmic and routine. There are no seven- or ten-step procedures that will mechanically produce a radical new process design." Research-oriented methodologies or initiatives for methodologies do exist but there are relatively few of them. In saying this, we ignore mere listings of activities that should take place within a Business Process Re-engineering (BPR) project without describing in some detail the activities themselves, the dependencies between these activities, the techniques that should be applied, and the deliverables of the activities.

We will use two criteria to further classify and discuss the technical BPR literature on design methodology. The first criterion is the *starting point* of a new business process design. The second criterion is the *method* of designing the process, which we see as the core of any BPR methodology. As will be shown, dependencies exist between these criteria. Other, but less distinctive, comparison factors include the process of strategy forming and process selection. There are three possibilities for the development of a new business process. One can do any of the following:

1. Take a clean sheet approach whereby the process is designed from scratch;

2. Take the existing process as a starting point; or

3. Use a reference model as a template for the new process.

There is considerable discussion in literature on the choice between the first and second alternative. See O'Neill and Sohal 1999 as an example. The opponents of the clean sheet approach identify four major drawbacks, leading them to advocate using the existing process as a starting point. These drawbacks are:

- There is the danger of designing another inefficient system (O'Neill and Sohal 1999);
- The clean sheet approach fails to build on knowledge and experience which has been built up over time and risks including mistakes already identified in past versions (Leymann and Roller 2000), (Kettinger, W.J., Teng, J.T.C. and Guha, S. 1997), Peppard, J., Rowland, P. 1995);
- Workers may be unable to relate to the new process as it bears little resemblance to the work that is being undertaken (Peppard and Rowland 1995); and
- By designing a process completely from scratch, the scope of the re-design problem is not appreciated. As Leymann and Roller 2000, Kettinger, Teng, and Guha (1997), and Peppard and Rowland (1995) suggest.

On the other hand, Peppard and Rowland 1995 identified that a drawback of taking the existing process as a starting point is the fact that process innovations are less likely to occur, although not impossible. Hammer and Champy 1993 are very clear about their preference: "Re-engineering is about beginning again with a clean sheet of paper. It is about rejecting the conventional wisdom and perceived assumptions of the past. Re-engineering is about inventing new approaches to process structure that bear little or no resemblance to those of previous eras." In favour of the clean sheet approach, Gulden and Reck 1991 state that the secrets of designing a process "lay not so much in intimately understanding the way it is performed today, but rather in thinking about how to reshape it for tomorrow." Peppard and Rowland 1995 identify the dangers of analyzing existing processes in too great a depth and becoming constrained by them when trying to think of new ways of working.

Taking the existing process as a starting point is, in practice, the most common way of developing a new business process as observed, for example, by Aldowaisan and Gaafar 1999. Peppard and Rowland 1995 suggest that the clean sheet approach has more attraction for Western companies, while Japanese manufacturers try to work from existing processes. This may be due to cultural and economic differences. They also note that it is common to see organisations occasionally start the design of a new process from a clean sheet, after which they apply several smaller improvement projects to the newly designed process as a means of continuous improvement.

The third possible starting point for a new process design is known as a reference model. The reference model serves as a template for a business process design that can be subsequently refined to match the specific demands or objectives of the business process. The MIT Center for Coordination Science (Dellarocas and Klein, 2000) maintains a repository of this kind of business process template for specific fields of operations.

Reference models are usually derived from earlier process design outcomes and typically describe essential process ingredients on an abstract level. Therefore, a reference model approach can be seen as a compromise between a clean sheet and an existing process approach. Existing processes are the inspiration for the re-design, although it may be radically new to the organisation in question.

Concerning the *method* of designing the process, a possible classification of the existing BPR methodology is as follows:

1. Participative methodology: based on involving and stimulating a group of experts in the design of a new business process.

2. Analytical methodology: based on an explicit recognition of design parameters and degrees of freedom, using algorithms or logic to create a new business process. Obviously, these characteristics are not entirely mutually exclusive.

2.4 PROCESS RE-ENGINEERING AND PARTICIPATIVE APPROACHES

Another approach for workflow process modelling is to use a *participative* methodology as described by Reijers and Voorhoeve 2000 and aimed at supporting a participative Business Process Re-engineering (BPR). Kettinger, Teng and Guha 1997 also used the participative approach through brainstorming and thinking outside the box as the techniques to support the re-design workflow through BPR. Generally, the participative approach involves the design of a new business process by encouraging consultants, specialists, employers and managers within the setting of a workshop to think of alternatives to the existing business process or to think of completely new processes. The workshop approach is used to entice people to abandon the traditional beliefs they may have about the process in question. A well-chosen delegation of internal specialists and managers should ensure that all expertise is available as is required to design a workflow process. Sometimes, consultants or academics are also hired for their intrinsic knowledge of a specific field of operations. Both Peppard and Rowland 1995 and Sharp and McDermott (2001) describe such a workshop-centred approach as offering a significant contribution to the design workflow and business process.

2.5 INTER-WORKFLOW DESIGN APPROACH

Companies embark on business design projects to try to streamline business throughput using workflow re-engineering, to reduce expenses or overall completion time or to maximize output. The goal is to continuously improve the way that the organisation produces its deliverables through optimized workflow management.

Workflow design and modelling are not new. However, many workflow systems in the public sector such as the Department of Transport (our industry partner) established in the last two decades, have not been a concentrated effort to look at an overall business workflow and design the way that intra- and inter-organisation staff and partners will work to effectively achieve business objectives.

The linking of workflows across organisations requires agreement among them as to how the workflow is to be divided among them and what kind of information is to be shared. If, for example, the procurement workflow in one company is to be coordinated with the ordering and delivery management workflow in the supplier companies from which it procures materials, then the procuring company must make this known to the supplier companies, or reach agreement on such matters as the types, format and timing of information they need to submit in order to participate in the procurement, the kinds of actions the suppliers must take in connection with the procurement, and the procedures involved.

Three steps are required for forming such an agreement.

1. The first step is that of modelling the inter-workflow, specifically, determining the division of the workflow in each organisation, deciding how information is to be shared, and defining the work procedures. This step takes an overview of the work and information flow in each organisation and studies the best form for the work to take.

2. The second step is to analyze the contents of the model and use simulations or other means to study the desired form. The results of this step are fed back to the modelling step.

3. The third step is to check the results of the modelling carefully so as to achieve strict definitions, eliminating error and ambiguity.

We believe support functions, like the following, need to be provided to assist these three steps.

- A formal language for writing inter-workflow definitions;
- A graphic inter-workflow modelling tool; and
- Analytical tools for simulating inter-workflow, using animation and the like.

A support environment that integrates these functions seamlessly is essential. In particular, the formal definition language is a foundation for realizing the other two functions, making this function especially important.

The inter-workflow in the three steps described above defines an inter-linking process to be carried out among the workflows of a number of organisations. For actual execution on a system as a workflow, not only must the linking with other workflows be defined, but it must be specified how the workers are to carry out the activities in each workflow. Moreover, the workflow designed in this way needs to be linked properly with the other workflows in accordance with the inter-workflow definition.

For designing workflow based on this kind of inter-workflow definition, assisting functions are essential to facilitate the design process and ensure it is done accurately. No matter how carefully the inter-workflow is defined, it will be of little worth if errors are made in workflow definition at the stage of designing it in each organisation. In fact, the lack of such a support function in last year's research resulted in a number of challenges arising, such as inconsistencies among different workflow definitions and misdirected data between organisations.

To solve such problems, the following support functions need to be provided:

- A mechanism for semi-automatic generation of corresponding workflow definitions from the inter-workflow definitions, in order to simplify the workflow design process; and
- A mechanism for checking whether a workflow definition is consistent with the inter-workflow definition.

These support functions are based on the aforementioned formal language for describing inter-workflow, and it is necessary to realize a consistent support for implementing a function for conversion from the descriptions and for testing the appropriateness of the descriptions.

Managing the workflow operations of each organisation in the collaboration must be done in a distributed environment. Since the inter-workflow defines the process of linking different workflows, naturally the operation management takes place across different workflows. Moreover, those workflows are not constructed on the same management system but are distributed across the systems of each organisation. The inter-workflow for international procurement, for example, includes the procurement workflow and also the ordering/delivery management workflow of each supply company; and these workflows are likely to be distributed across the procuring company's system and the systems of each of the supplier companies.

The following support functions are necessary for implementing operations management of workflows in a distributed environment.

- A mechanism for controlling execution of workflows designed on other workflow management systems;
- A mechanism for exchanging information with workflows running on other workflow management systems; and
- A mechanism for monitoring the status of workflows running on other workflow management systems.

2.6 INTER-TRADING APPROACH TO WORKFLOW DESIGN AND MODELLING

The inter-trading approach to workflow design and modelling includes both the digital transformation of recognizable commercial activities and the creation of new business rules and roles for participants in the business processes. The delivery of business through inter-trading involves the deployment of business processes for which workflow is a key supporting technology, and the delivery of goods and services through inter-trading involves the operation of businesses that run across and between organisations.

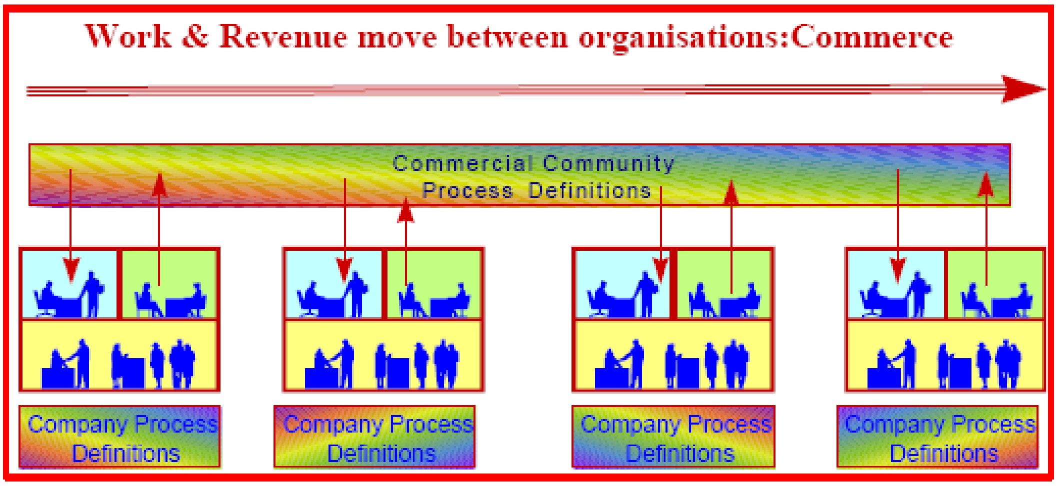


Figure 2-1: Value Chains that Run Across Organisations

An example of the inter-trading approach is the value chains that run across and between organisations. Technology such as Electronic Document Interchange (EDI) has, for some time, provided a reliable regime to support inter-trading between consenting organisations. Inter-trading is affected by the exchange of messages containing standard business objects (documents such as invoices, purchase orders and electronic funds) which are treated as input to the receiving organisation's IT systems. Inter-trading is well suited to support secure, high volume, transactional inter-trading workflows; however, it is expensive to set up and inflexible once in operation.

2.7 TASKS AND DECISION BASED WORKFLOW MODELLING

Business processes that operate within, across or between organisations in order to implement value chains that can be used to deliver business objectives may be designed using a set of workflow decisions that have been created to support discrete segments of the overall business process. This scenario poses the question of how to avoid creating islands of automation in the operation of an end-to-end business process. The answer to this problem is workflow interoperability – the enabling of different workflow products to *'talk to each other'* by exchanging messages that affect process interoperation and integration to drive and manage the operation of the value chain. Workflow interoperability enables the owner of the value chain to have greater visibility and control over its performance, and participants within the value chain benefit from flexibility, improved control and visibility of the performance of the processes they operate and the processes with which they interoperate.

Approaches that are more than just a summary of BPR principles and come close to being an analytical design methodology are provided by Orman 1998, Aldowaisan and Gaafar 1999, van der Aalst 2000b and Hofacker and Vetschera 2001. We will discuss each of these and compare them with the task-oriented approach presented in the remainder of this section. Orman 1998 presents a so-called *model management approach* in which business processes are seen as decision models. The purpose of a business process is to limit an initially wide search space until a decision can be made. Decisions in a business process reduce uncertainty. For example, the tasks in a business process to decide whether a mortgage loan should be granted may involve checking whether an applicant is a home owner and whether he or she has sufficient salary to cover repayments. Only applicants that satisfy all specified criteria may be granted a mortgage loan. Based on a given set of tasks, each with a specific cost and an expected reduction rate of uncertainty, an optimal ordering of tasks can be given in terms of expected cost. The model management approach also incorporates the issue of whether tasks within a business process should be shared across different processes. These results are less convincing, as Orman believes that sharing may lead to different ordering. This is not quite justified in the light of WfMSs. Note that the model management approach does not take an initial process structure as the starting point.

Aldowaisan and Gaafar 1999 present an approach, that takes a process design structure as a set of logically related tasks on the one hand and resources that yield a certain output on the other. In the first phase of their approach, the heuristics of Hammer 2002 are used to eliminate, integrate and automate tasks within an existing business process to create a better design. In the second phase, it is assumed that the search space for a further improved design structure is defined by two parameters: the number of employee types and the number of process tasks. In their approach, all different mapping of tasks on resource types are evaluated, the so-called *process mappings*. They proceed to show how to find the optimal process structure by balancing a quantitative cost and qualitative profit interpretation. Cost is expressed as the amount of training required to let resources perform tasks of which they were not initially capable. Profit is measured in terms of a simplified resource structure (fewer resource types) and the degree to which the case manager principle can be implemented (as few people as possible execute tasks for a specific case). A final check on the feasibility of the process map is executed by checking whether a sufficient number of resources are available. Note that Aldowaisan and Gaafar follow the same route of designing the routing component first and successively the allocation component as we have proposed in the introduction of this chapter. Van der Aalst and Jablonski (Aalst, W.M.P. van der, and Jablonski, S., 2000) focus on the design of a typical pattern found within many workflow processes in practice, a so-called *knock-out process*. A knock-out process consists of a set of tasks that are used to decide whether a specific case should be accepted or rejected. Each task may lead to a rejection – the knock-out – and only if all tasks have a positive result is the case then accepted. Van der Aalst and Jablonski (Aalst, W.M.P. van der, and Jablonski, S., 2000) provide a heuristic rule to order tasks within the same resource class to minimize the throughput time, given the rejection and failure rates of all tasks, as well as their average processing time. The applied model and optimization rule is similar to that of Orman (1998). Van der Aalst and Jablonski extend this heuristic to the case where different resource classes are available and an unbalanced occupation rate may affect the throughput time negatively. Heuristics are provided also for when to combine tasks so that by reducing set-up times the average throughput time is minimized. Finally, heuristic conditions are distinguished when tasks should be put in parallel, possibly yielding a shorter throughput time but also increasing the resource utilisation.

Hofacker and Vetschera 2001 approach a process design effort as the challenge of selecting the right subset of tasks out of a set of *potential* tasks. In their basic model, a task consumes one input and produces one output. They refer to these inputs and outputs as 'resources'. At the start of a process design, an initial set of resources are available and another set of resources are desired as the global output of the process. A process design is a totally ordered subset of tasks which is said to be feasible if:

- Each task's input is available when it starts (either because it is part of the initial set or because it is produced by a preceding task); and
- All global outputs are produced by executing the tasks in the design.

Three solution strategies are investigated for finding such a subset, respectively mathematical programming, direct branch and bound methods, and genetic algorithms. They show that the first two strategies deliver results with an acceptable performance for rather small models. Although the formalization of the problem in their approach is rather elegant, it is characterized by an overly simple structure of the optimization function. In particular, the specific ordering of the tasks does not affect this function; it takes into account only the membership of a task in the process design. For example, the effect of parallel executions of tasks on the speed of processing cannot be measured. Also, alternative paths cannot be incorporated in their notion of feasible processes, which is a strict abstraction of real workflows.

The focus of each of the four described approaches differs. We will elaborate on these differences by using the phases in a BPR effort as distinguished by Van der Aalst and Van Hee 2002. Orman 1998, Van der Aalst 2000b, and Hofacker and Vetschera 2001 focus on deriving an optimal routing component while the main point of the approach by Aldowaisan and Gaafar 1999 is to determine an allocation component on the basis of a given routing component. In the view of Van der Aalst and Van Hee 2002, designing the process structure should precede the allocation of resources. In this sense, these two types of approaches are supplementary. All four described approaches share the notion that tasks should exist before the approach is applied. Aldowaisan and Gaafar 1999 do allow for an initial phase where task elimination, integration and automation can take place and Van der Aalst 2000b even gives guidance regarding when to combine tasks. However, the analytical framework does not incorporate an evaluation of *what* should be done: which tasks are relevant for successfully executing the business process. This is one of the major distinctive factors of the approach that we will present in the following sections. We argue that this aspect is required for any approach to be applied as a model of a workflow methodology.

2.8 DISTRIBUTED WORKFLOW MODELLING

Distributed workflow was developed due to the evolution of supply chain management. It addresses all the significant activities that occur from accepting an order through to the delivery of the finished product. Workflow modelling in supply chains requires the modelling of all active participants including wholesalers, haulers, manufacturers, brokers and bankers as well as customers and their relative roles in the supply chain.

A supplier operating within a supply chain will typically undertake four basic business processes:

- Planning: begins when the supplier's customer attempts to place an order. The planning process enables the supplier to reconcile when the customer *wants* the goods with when they *can* actually have them. It also deals with mundane matters such as production scheduling, inventory management and transport scheduling.

- Sourcing: deals with ordering of materials, delivery scheduling and processing of invoices.
- Making: is the manufacturing process that results in finished goods.
- Delivering: deals with how the finished goods move from the supplier to the next point of activity within the value chain.

In the past, manufacturers were the drivers of the value chain, controlling the pace of production and distribution of goods. Today, customers are much more demanding and in many industries have taken ownership of the value chain. In such a competitive climate, modelling the workflow participants in the supply chain, we must model the dynamics of their business processes to cope with rising customer demands for more choice, more efficient production, speedier, more predictable delivery and even the ability to track progress on order fulfilment in the supply chain workflow model.

The following is a supply chain workflow that, in various forms, has been used as the basis of a number of interoperability experiments by supply chain companies.

The workflow describes the life history of an order fulfilment for a product (for example, a new sofa) from a retailer (for example, a mail order company) which places orders with manufacturers rather than retaining stock itself. The retailer must therefore make arrangements with the manufacturer to produce the goods (a new sofa) and with a transport company to deliver the goods to the customer.

Figure 2-2: The Order Fulfilment Scenario

Each participant in the supply chain uses a *workflow engine* to manage the processes it operates to deliver its contribution towards order fulfilment. A *workflow engine* is a software product used to manage the routing and scheduling of task-oriented work according to a preordained *process definition*. When a new process starts (say a customer places an order), the workflow engine reads the appropriate process definition and starts the first defined *activity* which, in the case of the retailer, may be to display an order form for completion.

Each new process that commences on a workflow engine is known as a *process instance*. A process instance is a defined thread of activity that is being *enacted* (managed) by a workflow engine. Most workflow engines can report on the current status of a given process instance.

When an activity is completed (in this example, the order form has been filled in), the workflow engine uses the process definition to decide what to do next. The next activity might be for an order to be placed with the manufacturer to make a new sofa. To place the order, our scenario says that the retailer’s workflow engine makes a request to the manufacturer’s workflow engine to start enactment of a process instance that will manage activities associated with the:

1. Production schedule

2. Delivery schedule

3. Manufacture

4. Proof of dispatch

5. Billing related to the production of the sofa (example)

To make this happen, the retailer’s workflow engine will send a message to the manufacturer’s workflow engine requesting that it start an instance of its order fulfilment process. Elements of process relevant data that must be included in the message in order to instantiate (pass values for process variables) the process model may include:

- Order number
- The product code (identifying the product as a sofa)
- The colour of the sofa to be made
- The customer’s name
- The delivery address

- The date available for delivery to the customer

The first step in the manufacturer's defined process is to invoke a Material Requirements Planning (MRP) application to schedule production of the sofa. Once the date when the sofa will be ready for dispatch has been established (returned to the workflow engine by the MRP application), the process moves onto the next step which is to book delivery with the transport company. This is done in the same way that the order was placed with the manufacturer. A message is sent to the transport company's workflow engine requesting that it start an instance of its booking delivery process and providing the following elements of workflow relevant data to instantiate the process definition:

- Where to pick up from
- What to pick up
- Value of goods to be shipped
- Delivery address
- Name of recipient
- Date for collection
- Collection time
- Date for delivery
- Delivery time

The transport company will schedule the delivery and return the confirmed delivery date to the manufacturer's workflow engine.

The manufacturer's workflow engine will return confirmation of the delivery date to the retailer's workflow engine, which will then send an invoice to the end customer, stating details of what has been ordered and when it will be delivered.

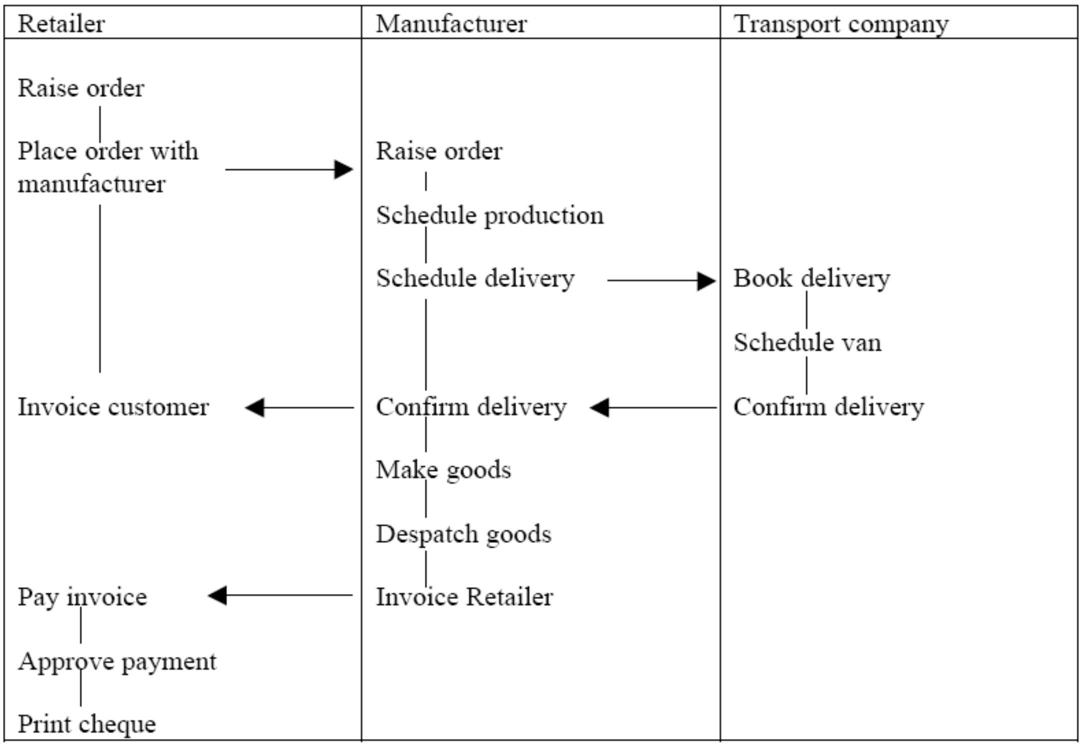


Figure 2-3: The Order Fulfilment Process Flow Diagram

The manufacturer and transport company processes are modelled as *nested sub-processes*. That is, they provide information back to their parent process instance enacted on the workflow engine that requested their invocation (see the process flow diagram for order fulfilment above).

An extension of the above scenario illustrates a second class of workflow interoperability based on the use of *chained sub-processes*. Having produced the sofa and dispatched it to the customer, the manufacturer raises an invoice with the retailer requesting payment. This is done electronically by the manufacturer's workflow engine requesting the retailer's workflow engine to start an instance of its 'pay invoice' process and providing it with the following information (as an example):

- Invoicing company
- Amount
- Item purchased
- Order number
- Dispatch date

In order to instantiate the process definition, the first step in the pay invoice process is an approval step. Assuming the payment has been approved, a cheque will be printed and sent to the manufacturer by post or by electronic transfer. The manufacturer's process ends once payment has been requested. A *chained sub-process* is one in which the parent process starts a process instance on another workflow engine but takes no further interest in its progress.

It is our expectation that *chained sub-processes* will be used more within organisations where they will be treated as members of a set of trusted processes deployed to support operation of the business. *Nested sub-processes* are more likely to be used in those business contexts where rendezvous and co-ordination are material to the operation of the business process or where it is important that the parent process track or maintain operational control over the operation of the sub-process.

For all of this to be possible, there will need to be a commercial agreement in place between each pair of companies that trade in the value chain. The companies will also have established a technical agreement (an *interoperability contract*) describing the way in which interoperability is to be affected. The technical agreement will cover aspects such as:

1. Which workflow engines within one company are visible to/capable of interoperating with which workflow engines in the other company;

2. Which workflow definitions can be enacted within one company at the behest of workflow engines in the other company;

3. The transport binding supported (e.g. MIME1, jFlow, SWAP,…);

4. For each workflow definition identified in the contract:

- Values that must be supplied or can be returned

- Each traded (shared) element of *workflow relevant data*

▪ Access rights (whether the element is readable/writable)

- Value constraints (minimum/maximum values, number of permitted updates/accesses)
- Outcomes/outputs/returned elements of workflow relevant data
- Audit data policy
- Change control policy

5. Security policy and implementation of:

- Authentication
- Support for/ policy on non-repudiation
- Shared key cryptography and key management
- Handling security breaches; and

6. Exception handling/recovery protocols and transactional behaviour.

Individual interoperability contracts will have a unique identifier, determined by the organisations trading across the service boundary, which is used to support authentication mechanisms.

2.9 BPR PRINCIPLES AND APPROACHES

Business Process Re-engineering (BPR) builds upon analytical techniques to produce a new workflow design. Hansen (1994) argues that the complexity of BPR efforts requires scientific, analytical techniques, as non-analytical, informal approaches lead to many failures of Business Process Re-engineering projects. He claims that business process behaviour depends on many interrelated parameters, which cannot be dealt with in an informal way. However, most of the material that relates to analytical BPR methodology does not really qualify as mature methodology. Rather, these are technical principles or heuristics that may be used to create superior new business processes. Hammer and Champy 1993 present technical

BPR principles, for example: tasks in a business process should be combined into larger tasks, a case manager is appointed as a single point of contact, and the number of checks and controls in a process should be reduced. Similar principles are presented by the following researchers:

- Rupp and Russell 1994 offer a summary of sixteen principles including avoidance of intra-organisational dependencies and shared responsibilities, create more multi-skilled workers, design activities to run in parallel paths.
- Peppard and Rowland 1995 identify and break down four core groups of principles that must lead to the elimination, simplification, integration and automation of work.
- Berg and Pottjewijd 1994 identify and illustrate six forms of process improvement: elimination, integration, broadening, parallelization, volume increase, and effectiveness increase.
- Poyssick and Hannaford 1996 list thirty-six process improvement rules.
- Van der Aalst and Van Hee 2002 list fifteen heuristic rules for the re-design of workflows such as initially ignoring the existence of resources when designing, consider specialization of generalized tasks, let resources work on the same case as much as possible.

Most of these directions are characterized by the tacit assumption that an existing business process is taken as the starting point of a new design. By locally applying a re-engineering principle, the performance of the total business process is boosted. The principles presented are often derived from experience gained within large companies or by consultancy firms with repetitive application of these principles in BPR engagements. For example, the rules as proposed by Peppard and Rowland 1995 are derived from the experiences of the Toyota Company. Generally, many of the BPR principles lack an adequate (quantitative) support, as noted by Van der Aalst (2000a) for example. Buzacott 1996) Seidmann and Sundararajan 1997, Van der Aalst 2000b, and Zapf and Heinzl 2000 provide analytical or quantitative support for the superiority of some of the BPR principles available.

2.10 PRODUCT-DRIVEN WORKFLOW DESIGN AND MODELLING

In this section, we will first outline the Product Driven Workflow Design (PDWD) methodology. Then we will discuss each of the phases in more detail including a description of their deliverables. The phases that can be distinguished within a PDWD effort are as follows:

1. Scoping

In this initial phase the workflow is selected that will be subject to the re-design. The performance targets for this workflow are identified, as well as the limitations to be taken into consideration for the final design.

2. Analysis

A study of the product specification leads to its decomposition into information elements and their logical dependencies. The existing workflow, if any, is diagnosed to retrieve data that is both significant for designing the new workflow and for the sake of evaluation.

3. Design

Based on the re-engineering objectives, the product specification decomposition and estimated performance figures, several alternative workflow structures are derived. A workflow structure consists of tasks that retrieve or process information elements.

4. Evaluation

The alternative workflow structures are verified, validated with end-users, and their estimated performance is analyzed in more detail. The most promising designs are presented to the commissioning management to assess the degree to which objectives can be realized and to select the most favourable workflow design.

These phases are presented in a sequential order but, in practice, it is very plausible and sometimes desirable that iterations will take place. For example, the evaluation phase is explicitly aimed at identifying design errors which may result in the design being reworked. The focus of this section will be on the analysis and design phases of PBWD.

The Industrial Revolution at the end of the eighteenth century called for a new type of organisation: labour became divided into specialties. This principle allowed for a fantastic increase in production output on the factory floor. Soon afterwards, this principle was applied in the growing field of office work with similar success. Product-Based Workflow Design (PBWD) is a workflow design methodology that also translates a typical manufacturing concept to office work – the common context of workflows. In section 1.7 we already explored some of the differences and similarities between workflow and logistical management. A typical characteristic of manufacturing is that the structure of the product is used to determine the manufacturing process. This principle is illustrated in Figure 2.4.

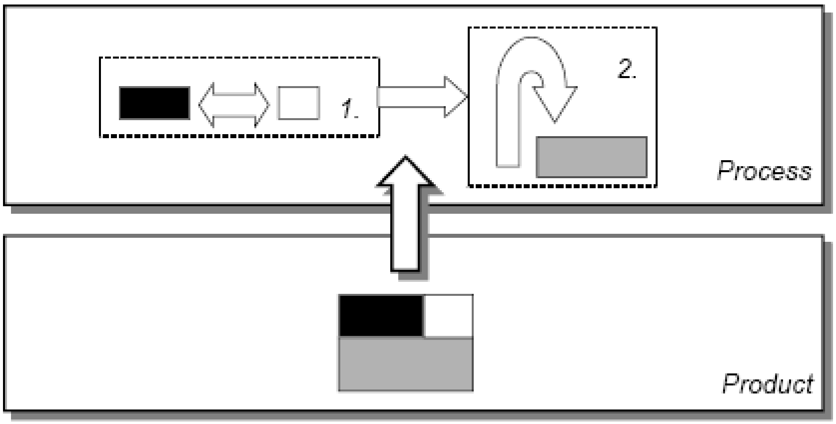


Figure 2-4: The Relationship Between Product and Process

The figure above shows how the structure of a product is used to determine the steps that should be taken to manufacture it, that is, the process. The product in Figure 2.4 is schematically depicted as a large box. This box consists of three smaller black, white and grey boxes, which are combined in a specific way. The depicted process to produce such a product first fits together the black and white box (step 1), after which this subassembly is placed on top of the grey box (step 2). It is clear that this simple production process indeed delivers boxes with the desired elements and composition. Note that without further restrictions it seems possible to design alternative ways to produce the same product. For example, by first fitting together the black and grey boxes and then placing the white box between them.

The structure of the product in manufacturing is specified with a Bill-Of-Material (BOM) (Orlicky, 1972). The BOM is a tree-like structure with the end product as root and raw materials and purchased products as leaves. In the resulting graph, the nodes correspond to products including end-products, raw materials, purchased products and subassemblies. The edges are used to specify composition relations (*is-part-of* relations). The edges have a cardinality to indicate the number of products needed. Figure 2.5 shows the simplified BOM of a car, which is composed of an engine and a subassembly. The subassembly is composed of four wheels and one chassis.

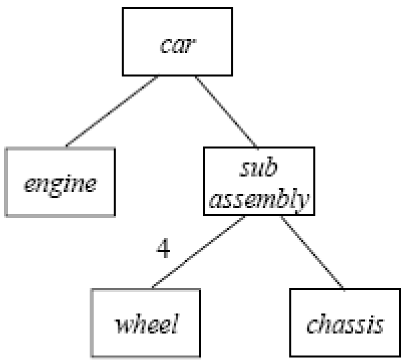


Figure 2-5: The BOM of a Car

If we take a look at, for example, Material Requirements Planning (often referred to as MRP-I), we see that it determines the production schedule based on the ordered quantities, current stock, and the composition of a product as specified in the BOM. Contemporary Enterprise Resource Planning (ERP) systems such as SAP also take resource availability into account and use more refined algorithms.

The important observation here is that the manufacturing process is driven by the *structure of the product*. For example, in the production line for cars with a BOM as in Figure 2.5, the subassembly of the wheel and chassis will precede the final assembly step of the entire car.

In contrast to manufacturing, the product and the process have often diverged in actual workflow processes. Workflows found in banks and insurance companies for products like credit, savings and mortgages, damage and life insurance and so forth, may well exist for decades. Since their first release, those processes have undergone an *organic evolution*. For example, historical problems in performing certain computations have resulted in the addition of calculatory checks.

Another example is the effect that a historical case of fraud may have on a process. A very restrictive type of control may be added in response. Aside from the evolutionary changes of the process, the state of technology of some decades ago has considerably influenced the structure of these workflows permanently. For example, it used to be laborious to make a copy of a client file. Therefore, in many actual workflows a highly sequential structure of tasks can be distinguished, where at most one person at a time works on an order. It is difficult to migrate from this original set-up of a workflow in an evolutionary way. In summary, the structure of an actual workflow may no longer be related to the product characteristics.

Clearly, for manufacturing process and workflows alike, there is a relationship between the product and the process: the very justification of a workflow's existence is the generation of a specific type of product. As we have argued in section 1.4.2, workflows are mostly of the mass customization type. On the basis of a clear priori notion of a standard product, product instances are delivered to clients, which may be slightly customized to the preferences of the client in question. The characteristics of the standard product are often described in administrative procedures, marketing material, internal regulations and product development materials. Mass customization is also accompanied by a high turnover volume. Financial institutions, utility companies, and government agencies are typical sectors that deliver mass customized products. The loose coupling between the product notion and the process structure in this setting is, at closer inspection, rather mysterious. We propose that an analysis of the product specification may be a feasible and attractive starting point for designing workflow processes in this area. This is the fundamental idea behind PBWD.

To see how this would work, consider the example of the processing of insurance claims. The product to be delivered on the basis of an actual claim is basically a decision: either the claim is accepted - followed by a payment - or the claim is rejected. Note that this way of looking at a workflow as a knock-out process is similar to some of the design methodologies we presented at the end of the previous section. All kinds of *information elements* may play a role in making this decision, such as the amount of damage, the claim history of the claimant, and the coverage of the insurance. For example, one of the standard conditions of the insurance policy may specify that if the amount of damage is below a certain threshold, the claimant has not issued a claim for over a year *and* the damage is covered, then the claim is accepted and the damages compensated. This hypothetical condition can be seen as part of the insurance *product specification*. The information elements can be seen as raw materials or subassemblies for the production of a decision. The workflow process should 'manufacture' the decision by distinguishing tasks to retrieve and assess the required information elements, while taking criteria such as average throughput time, service level, handling costs, and product quality into account. The latter are typically not characteristics of the product, but performance targets.

PBWD is a prescriptive methodology that is concerned with the *technical* side of BPR. It is not a project management approach; nor does it pretend to cover the change management issues of innovations. Note that the development of prototypes on the basis of PDWD deliverables may be an effective support of managing the change (see section 3.3.4). We defined the technical side of BPR in the previous section, as the issue of developing a process design that is a radical improvement of a current design. We identified the *starting point* and the *method* as distinguishing features of BPR methodologies in this field. Considering these features, PDWD takes a clean sheet approach. It explicitly does not take the existing process as a starting point. Furthermore, it is analytical in its approach in contrast to popular, participative approaches. Based on our literature survey, we conclude that it is one of the very few existing methodologies with these characteristics.

PDWD builds upon an idea as published by Van der Aalst (1999), where enhanced BOMs are described that allow for an automatic generation of workflows. Verster (1998) already described the decomposition of an informational product into data elements within the context of business process re-design. Although he proposes the structuring of this type of data for the purpose of simplifying the product and the process, no methodical derivation or optimization of the workflow from this structure is presented. These are specific characteristics of the PDWD design methodology, as will become clear from the following sections.

2.11 ACTIVITY BASED WORKFLOW MODELLING

2.11.1 **Activity Diagrams**

An activity diagram shows the flow from one activity to another activity. An activity is an ongoing non-atomic execution within a state machine. Activities ultimately result in some action, which is made up of executable atomic computations that result in a change in state of the system or the return of a value. Graphically, an activity diagram is a collection of vertices and arcs.

Activity diagrams allow representation of all the elements included in a workflow model: roles, activities, events, control and information flows, conditions and relevant data. It can also model concurrent events by making use of a synchronisation bar to specify the forking and joining of parallel flows of control. Figure 2.6 shows an example of an activity diagram.

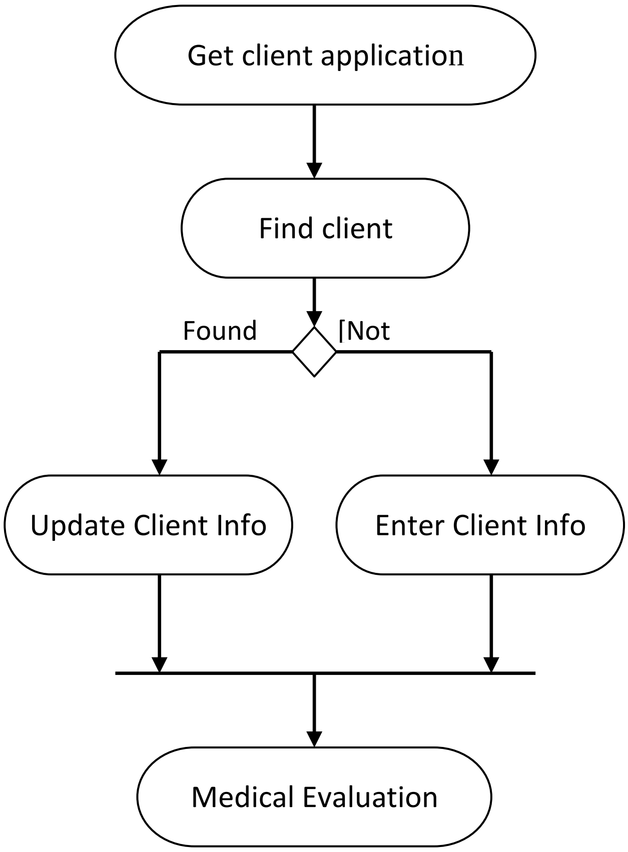


Figure 2-6: An Example of Activity Diagram

An activity diagram can capture activities and allow presentation of flexible choices in the model of a workflow. However, we found that the diagram cannot be easily scaled up to represent a complex, large-scale, workflow environment.

An activity diagram is good to model a small and simple workflow. Based on this observation, we choose an activity diagram as the foundation to solve our problem. In the next section, we discuss activity diagrams further and we propose to extend them so that they are suitable to model a flexible workflow model.

In general, a workflow is considered as a collection of activities for the accomplishment of tasks. Each sequence of activities has to be executed in accordance with the business process of the organization

2.11.2 **Activity Diagrams Based Approaches**

A major concern of workflow technology is to model business process logic properly and provide suitable support for its execution. Workflow technology can be fully exploited when predictable and repetitive processes are executed. Unfortunately, real-world business processes are unpredictable. In this era, the competition between vendors is so high that fast response to changing market requirements is mandatory in order to stay in business. For instance, the growing interest in e-commerce among companies has made them change the way they conduct business.

There are two types of flexibility: flexibility by selection/configuration and flexibility by adaptation as seen by (Berman, Fox and Hey 2003 and Boley 2006) Flexibility by selection gives the user a certain degree of freedom to execute a workflow by offering multiple alternative execution paths. It is useful when the number of execution paths for a workflow are either known and/or anticipated. However, flexibility by selection itself is limited by the requirement that it has to be anticipated and has to be included into the workflow model at the design stage. To support flexibility by adaptation, the workflow management system has to provide additional functionality and tools to change the workflow instance and to integrate these changes during runtime (Berman, Fox and Hey, 2003). Another approach to support flexibility by adaptation is by means of advanced inheritance concepts, which are proposed in Brandenburger et al. 1996. The inheritance concepts can be used to limit change, manage multiple version/variants, and avoid errors.

Other problems that have to be considered are accuracy and consistency issues. It is essential that workflow management systems be able to cope with changes, but it is also important that they be able to verify the accuracy and the consistency of the workflow definition, after the changes have been made. Changing a workflow definition can lead to a deadlock or a livelock. Transferring a case from an old workflow definition to a new one can cause a task to be executed more than once or not executed at all. Note that all these problems could arise when flexibility by adaptation is applied.

We are going to focus only on flexibility by selection, that is, the specification of flexible workflow execution behaviour to express a structured and unstructured business process in advance. Although, the flexibility by adaptation can overcome the lack of flexibility of selection, it should be limited to unforeseen and exceptional cases. Otherwise, the need for flexibility by adaptation indicates an inadequate workflow model, caused by inadequate model building or inappropriate modelling language constructs (Boley, 2006).

Since the flexibility by adaptation requires human intervention, it is important to have a workflow modelling language at a high level of abstraction, which is easy to use and supports the visualization of its contents (Chang, E. Dillon TS 2003).

2.12 PETRI-NETS-BASED APPROACHES

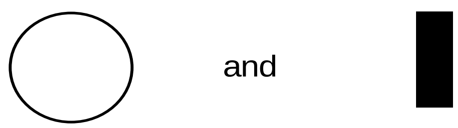
2.12.1 **Petri-nets Diagrams**

Petri-nets are a formal and graphical language that is appropriate for modelling systems with concurrency. As a graphical tool, Petri-nets can be used as visual-communication aids similar to flow charts, block diagrams and networks. In addition, tokens are used in these nets to simulate the dynamic and concurrent activities of systems; Petri-nets provide a means of estimating the time a system will take to proceed from initial state or set of conditions to desired final state. It consists of *places*, *transitions*, and *arcs* that connect them. *Input arcs* connect places with transitions, while *output arcs* start at a transition and end at a place.

W. Reisig (1991) says "Anyone who uses Petri-nets knows that it is a straightforward method... It is a practice-oriented method for a programmer who needs graphic models and techniques primarily as an illustration for himself, his colleagues and the users of his software". The mathematical foundation of Petri-nets is "Net Theory": the graphical syntax of Petri-nets is well defined and precise semantics exist for them. It is an important software engineering method and supports the coordination and information exchange between all parties involved in the development of software. It is often used in the modelling of communication protocols, parallel programs, hardware and distributed data processing.

There are 3 principles in Standard Petri-nets:

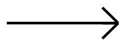
(1) Model the system as several pairs of State-Transitions or Condition-Events or Place-Transitions.



States	**Transitions**
Place	**Transitions**
Conditions	**Events**

(Patri-nets notation part A)

(2) Logical connections, links, access.

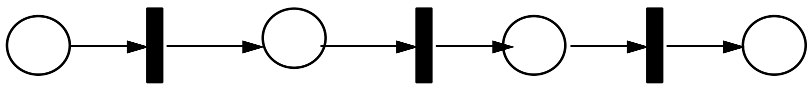


(Patri-nets notation part B)

(3) Must be State-Transition-State-Transition... or

Condition-Event-Condition-Event... or

Place-Transition-Place-Transition...



(Patri-nets notation part C)

Figure 2-7: Notation system for Petri-nets (above A-C)

Example of Petri-nets for a CPU process

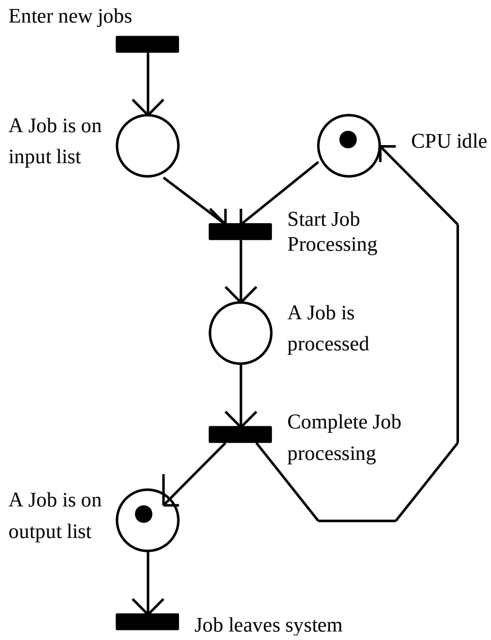


Figure 2-8: Example of Petri-nets for a CPU processes

Example of Petri-nets for Production Control

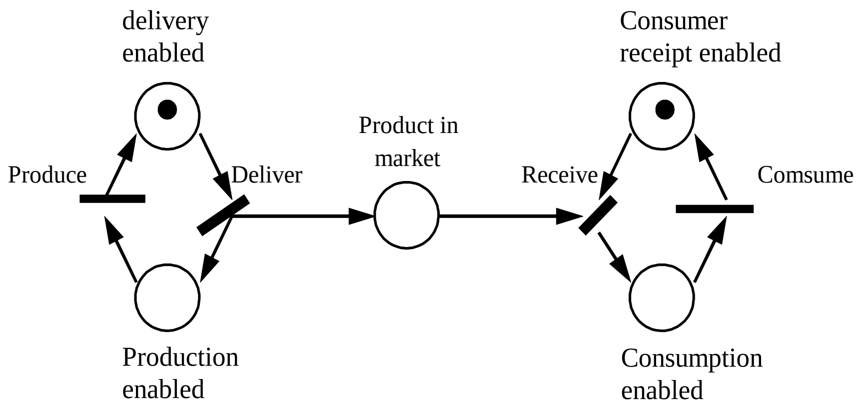


Figure a

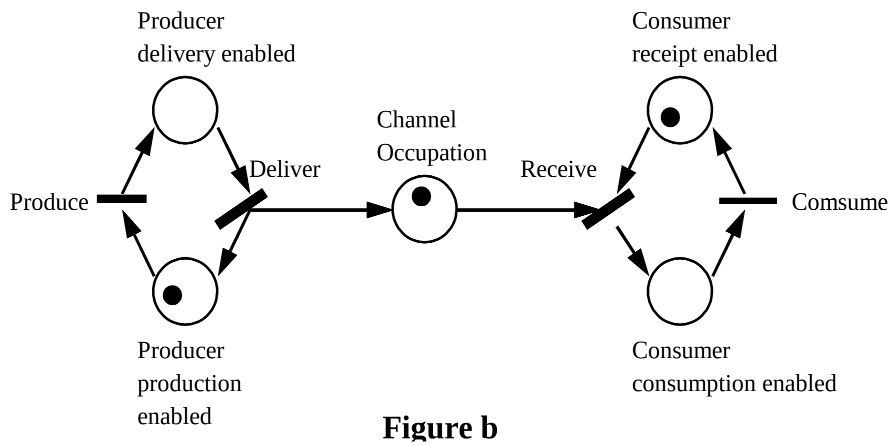


Figure b

Figure 2-9 (a) and (b): Example of Petri-nets for Product Production Control

If a product is ready to be delivered from the factory and the market needs it, then the "Deliver" will take place and put the product into the market. The factory can then "Produce" a new one.

If the product is in the market, and if the customer wants it, then the "Receive" will take place, then the customer will use it ("Consume").

Figure (a) and (b) above shows two fulfilled (True) and three unfulfilled (False) conditions. The Event “Deliver” is the only one which can occur.

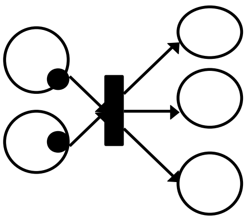
This is because the firing rule is "Event activated if all its pre-conditions are True and all its post-conditions are False".

After the event “Deliver” occurs, two further events “Produce” and “Receive” may occur.

As a result of these, the event “Consume” will be triggered. (Loop starts again).

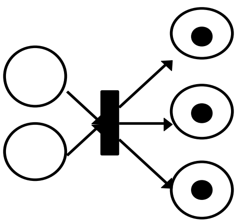
Coloured Petri-nets is that it adding **weight** on the firing rules. For example:

(a) An event is activated if all its pre-conditions are fulfilled (True) according to the weight and all its post-conditions are un-fulfilled (False) e.g.:



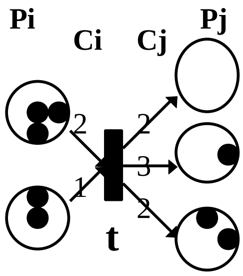
Example (a), the weight is equal to 1

If the event is activated, then pre-conditions become unfulfilled (false) and post-conditions become fulfilled according to the Weight, e.g.



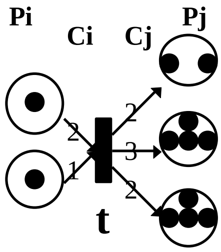
Example (b), the weight is equal to 1

Example (b) If Transition t is activated if token# in every place is greater than the weight Ci (means the # shows on the arrow-line) from Pi to t



Example (c), the weight is equal to 2 and 1

When a transition t occurs, the token# at every Pi is decreased by Ci, and the token# at Pj is increased by Cj.



Example (d), the weight is equal to 2, 3, 2

Figure 2-10: Firing rules with "weight" for Coloured Petri-Net

Figure 2.10 above shows a simple example of Coloured Petri-nets. In the literature, there are more than 20 types of Coloured Petri-nets. We will study these in detail and develop a new kind of Coloured Petri-nets together taking into consideration the Activities for modelling the collaborative workflow.

2.12.2 **Petri-net Diagrams Based Approaches**

In the literature, a lot of workflow modelling was through Petri-nets and they largely model the workflow result, and demonstrate how it worked. Coloured Petri-nets were used to help model parallel and asynchronous processes. Previous examples of coloured Petri-nets have always tried to model something that would work or how it should be working. We need a tool to enable the modelling of a real-time collaborative workflow in a complex environment and to identify where the issues lie. When using a Petri-net, time was used to consider the parallel process, such as the synchronous and asynchronous processes, but there was no consideration of how long, and there are no time frame constraints. In this thesis, we focus on the model with the time frame constraints, and if we have to stay with the same time frame, and if we have to add activities, we need to see the intensity and its positive or negative impact on the whole workflow activities within the collaborative business. We note that the modelling of the time frame and activities is linked to the question of managing the resources. We also note that Petri-nets are good for modelling one-way flow, not bi-directional flows. In this thesis, we will try to use Petri-nets to help model 'time constraints' in the collaborative workflow models.

For an event to be able to occur, a transition must have sufficient tokens on its input places, and these tokens must have token values that match the arc expressions.

The rules for executing the systems are:

- A transition is 'active' when each of its input places contains a token.
- Each active transition in the diagram is 'fired' by removing one token from each input place and generating one in each output place.
- A Change of State is denoted by a movement of token(s) (black dots) from place(s) to place(s); and is caused by the firing of a transition.
- The firing represents an occurrence of the event or an action taken.
- The firing is subject to the input conditions, denoted by token availability. A transition is firable or enabled when there are sufficient tokens in its input places.
- After firing, tokens will be transferred from the input places (old state) to the output places, denoting the new state. Petri-net diagrams allow representation of all the elements included in a workflow model: roles, transitions.

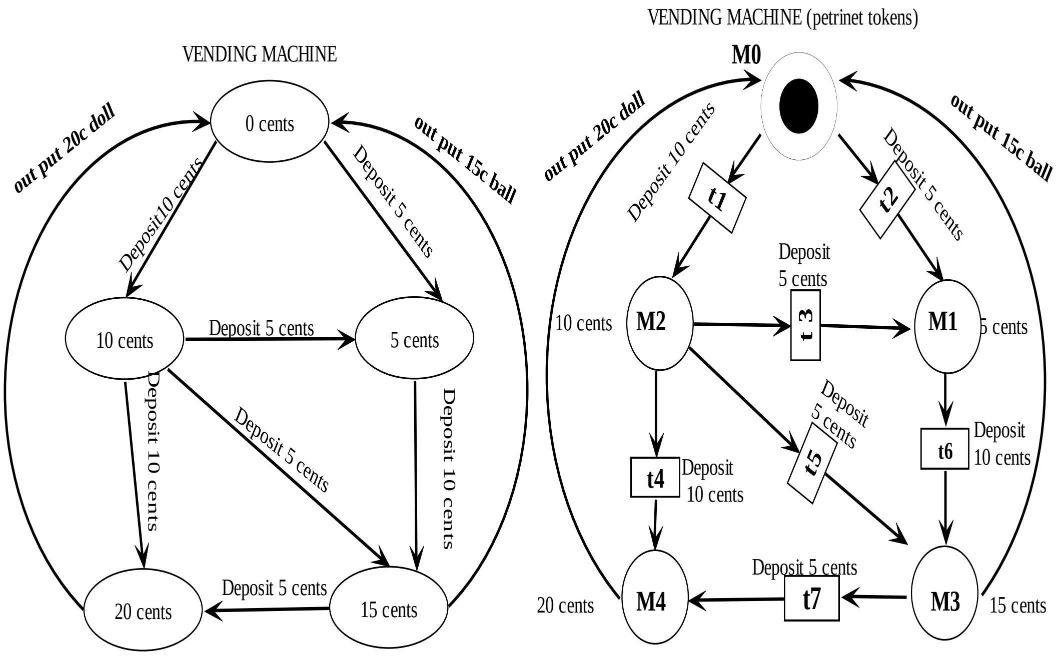


Figure 2-11: Petri-nets Modelling of a Vending Machine

$$M0 \xrightarrow{t1} M1 \xrightarrow{t3} M2 \xrightarrow{t5} M3 \xrightarrow{t8} M0 \xrightarrow{t2} M2 \xrightarrow{t6} M4$$

Figure 2-12: A Firing or Occurrence Sequence

2.13 UML BASED MODELLING TECHNIQUES

It seems natural to work towards object-oriented technologies and methodologies when we discuss flexibility and adaptability. The fact is that object orientation is very good for creating solutions for problems of expandability, maintainability and specialization of software applications. The intrinsic objects' characteristics, especially inheritance, encapsulation and polymorphism, make objects particularly attractive for finding solutions to the flexibility problems of workflow systems.

Unified Modelling Language (UML) is a language for modelling. Its primary function is to model a software application by utilising object-oriented methodology. However, some people believe that it can be used to model many other situations. It has several diagrams for modelling, one of which is the Activity Diagram. It is used to model the dynamic behaviour of a software application but it also can be used to model a workflow of a non-software application.

Some of the advantages that can be achieved from UML for the modelling of workflows are:

- UML is an object modelling language; therefore, models built using this notation are easily capable of integrating changes and are easily implementable.
- UML is or will be used by a large number of analysts and designers. The interest is, hence, to build models that can be understood by the largest number of people without introducing new modelling methods or formalisms. Indeed, we use the UML as it is prescribed in the notation. The target here is to make people in charge of modelling use tools and methods they know well and the high possibility of implementing the models that allow direct translation into the software code or a workable workflow system. However, we found that the model-driven approach is very sound in theory, but when we try to generate the code or a system from an UML model, it requires enormous customization and sometimes the system only partially works. Also, we found such an approach cannot scale up to capture large-scale workflow models.

2.14 META-DATA AND META-MODEL DRIVEN ARCHITECTURE (MDA)

There are so many different technologies that are used to develop a system and different platforms on which the same system can run. Therefore, it is necessary to model the business requirements using an independent means. This data can then be modelled on a specific platform from which one can implement the system; this is the concept of Model Driven Architecture (MDA).

It allows the requirements of the customer to be recorded in a clear and concise way to develop a system using a platform-independent model. Every day, new technologies are evolving and organisations have to keep up to date with them. Requirements from customers are changing and functionalities have to be added to the software already created, which may require new technologies. Therefore, to enable the integration of the old system with the new system and any other system created in the future, MDA has to be used. MDA includes the iterations of deploying, combining and managing data as well as applications. MDA is made up of a platform-independent UML model and one or more platform-specific models. In addition, the platform-independent model contains information about how the UML base model is implemented on the middleware platform.

2.15 WORKFLOW DECOMPOSITION APPROACHES

Business processes comprise two operational parts, one structured and one unstructured. They could also include semi-structured parts with some given and some unknown details. This situation raises problems in workflow design and workflow systems development. One of the problems with current workflow systems is that they cannot deal with unpredictable situations and changes. Unpredictable situations may occur as a result of changes by management. The inability to deal with various changes greatly limits the applicability of workflow systems in real-world industrial and commercial operations.

Workflow decomposition is usually concentrated on the operational aspects of the organisation or an enterprise (Roy and Ramanujan, 2000; also Han, Sheth and Bussler, 1998). Although operational aspects of workflow design are crucial to the organisation, we note that changes are passive, not dynamic. They change only when there is a management decision.

Liu and Ong (1999) in their paper state that in any organisation, a workflow can be decomposed into three categories: ad-hoc workflow, administrative workflow and production workflow. These three types of workflow are supported by three categories of workflow systems.

1. *Ad-hoc workflows* involve human coordination, collaboration, co-decision, and often appear in office processes such as product documentation or sales proposals.

2. *Administrative workflows* involve repetitive, predictable processes with simple task coordination rules, such as routing an expense report or travel request through an authorisation process.

3. *Production workflows* (automated tasks being performed repeatedly) production workflow encompasses an information process often involving interaction to one or more distributed/heterogeneous/autonomous information systems.

According to Hala Skaf-molli 2003, workflow can be categorised into four groups; Collaborative workflow, Production workflow, Administrative workflow and Ad-hoc workflow.

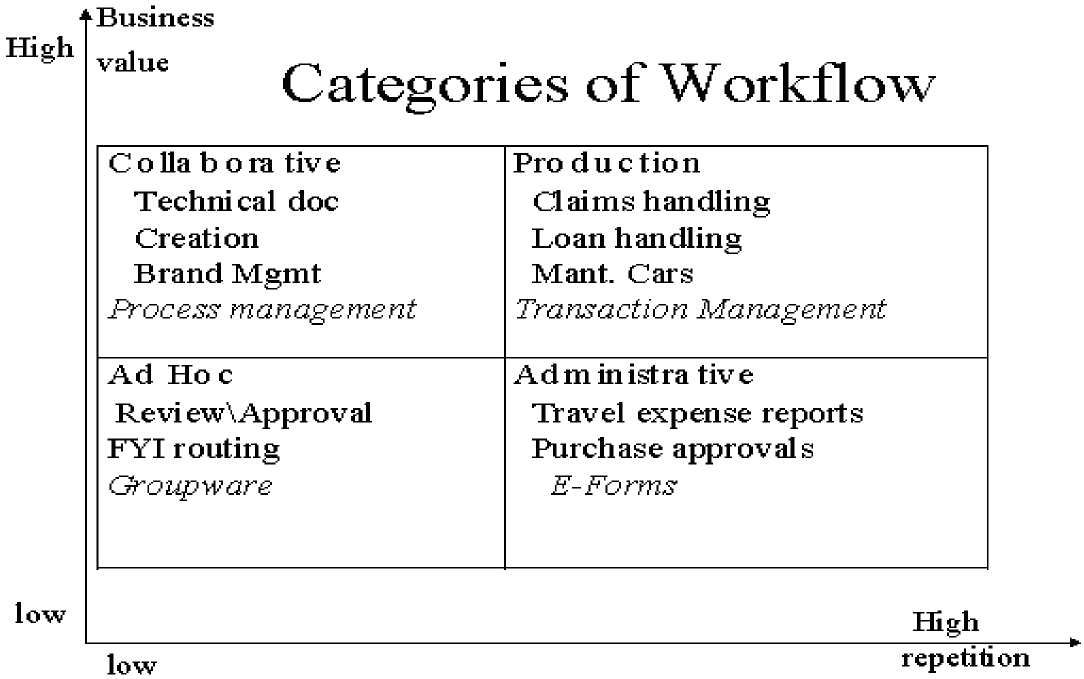


Figure 2-13: Workflow Decomposition by Dr Hala Skaf-Molli

The above workflow design separates workflow into workflow components, and indicates which workflow components are active and which are passive, how they respond to business changes, and how they manage the internal and external relationships of an organisation.

2.16 WORKFLOW MANAGEMENT SOFTWARE

Existing workflow software is facing a number of challenges in the collaborative environment. These include:

- Lack of interoperability
- Lack of support for legacy workflow systems
- Difficulty in capture the performance of the business processes
- Lack reliability
- Lack of support for analysis, testing, and debugging the workflows

*Lack of interoperability i*s directly attributable to the lack of standards for workflow management software or business information systems. The Workflow Management Coalition, a standards body, was formed in 1993 to promote interoperability among workflow management software or business information systems. Their standards address the areas of (i) APIs for consistent access to workflow management software or business information systems services/functions, (ii) specifications for formats and protocols between WFMSs themselves, and between workflow management software or business information systems and applications, and (iii) workflow model interchange specifications to allow the interchange of workflow specification among multiple workflow management software or business information systems. Most software vendors are members of this coalition.

Support for legacy system and integration, indicates that workflow information systems have full interoperability with other new or legacy workflow management software or business information systems because:

1. It simplifies workflow implementation, i.e., interoperability allows workflow management software or business information systems to access other workflow management software or business information systems without requiring any additional policies or procedures.

2. It allows fast workflow implementation,

3. It requires minimal workflow re-implementation to cope with changes in system

4. Functionality. That is, some commercial workflow management software or business information systems support limited interoperability among office applications meeting specific platform, interface, or operating system requirements. For example, some workflow management software or business

information systems (e.g. Lotus Notes) use Microsoft's OLE as a protocol for document interoperability.

However, further interoperability requires workflow management software or business information systems to take advantage of technology that complies with industry standards for interoperability, such as those developed by the Object Management Group (OMG).

Capture the performance. Commercial workflow management software or business information systems typically support no more than a few hundred workflows a day. Some processes require handling a larger number of workflows; perhaps a number comparable to the number of transactions TP systems are capable of handling. For example, telecommunications companies currently need to process ten thousand service provisioning workflows a day, including a few thousand service provisioning workflows per hour at peak hours. Commercial workflow management software or business information systems are currently not capable of handling such workloads.

Lack of reliability in the presence of concurrency and failures, indicates that a workflow execution (like any execution of applications that access shared resources) must address the following three *correctness* concerns: the consistency of individual tasks, the consistency of individual workflows (i.e., the consistency of concurrent executions of tasks that belong to the same workflow), and the consistency of concurrent executions of tasks that belong to different workflows. Usually, the person who performs a task is responsible for ensuring that the task produces correct results if it is executed alone. It is also reasonable to assume that if tasks are executed correctly one after the other in an order allowed by workflow specification rules such an execution of a workflow preserves consistency by design. However, if tasks are executed concurrently with tasks from the same or other workflows, and the tasks share resources, their individual operations may interleave in such a way as to produce incorrect results. These are well-understood issues in database transaction processing.

The workflow reliability problem involves restoring consistency when a workflow terminates abnormally (e.g. due to a system failure, lack of available resources, or inability to achieve objectives). Completed tasks of a partially completed workflow may be undone or compensated. Alternatively, incomplete tasks of a partially completed workflow may need to be redone or contingency tasks may need to be performed. Clearly, it is important to know which tasks have been completed, which are still active, which have not begun, and which tasks need to be undone or redone to restore consistency.

To deal with these problems, workflow management software or business information systems rely on (i) workflow designers to provide specifications that include compensating tasks and actions, and (ii) task/workflow programmers to provide code for concurrency control and log-keeping. This solution is unrealistic, as most workflow designers/programmers are not skilled in concurrency control and recovery technology. Moreover, the software needed to implement concurrency control and recovery mechanisms is complex. Finally, testing and debugging software with hardcoded correctness and reliability functions is time-consuming and error-prone.

Weak tool support for analysis, testing, and debugging of workflow specifications and implementations. Such tools are needed to estimate workflow specification and implementation efficiency, simulate workflow execution, and determine the source of workflow specification and implementation problems. The sophistication of such tools directly impacts on rapid prototyping, and ease of workflow specification and implementation.

The limitations of current workflow management software or business information systems can be attributed to their lack of standards and tools for conceptual modelling, testing, debugging, and analysis. Other limitations, however, are fundamental to the design of the workflow management software or business information systems we have investigated; this includes for example, lack of support for interoperability, as well as correctness and reliability support. In the following section, we discuss technologies that can be integrated with workflow management to address these limitations.

2.17 SUMMARY OF MODELLING TECHNIQUE

The existing workflow modelling techniques mentioned in the literature to help modelling the workflow and dynamic aspect of the workflow include Process Oriented Modelling, Business Re-engineering based approaches, Activity driven models, Task driven models, Product driven Models, Duong, D.D., Boley, H., Le, T.T.T., Bhavsar, V.C.,(2006). Aalst, W.M.P. van der; Basten T.; Verbeek, H.M.W.; Verkoulen, P.A.C.; Voorhoevoe, M.,(1999), Petri-nets Aalst, W.M.P van der; Jablonski, S., (2000) “Dealing with workflow change: Identification of issues and solutions”, *Special Issue of International Journal of Computer Systems Science And Engineering*, September 2000, UML Sequence Diagrams (Gautama, E Chang, E. 2001, Gantama, E., Chang, E., Jayaratna, N. & Pudhota, L., 2003).

There methodologies are well used in academia and some industries. A most popular used technique is the use of Petri-nets to model a workflow (Aalst, W.M.P. van der; Basten T.; Verbeek, H.M.W.; Verkoulen, P.A.C.; Voorhoevoe, M.,1999) Other Petri-nets methodologies that have been commonly used include Place-Transition Nets, and Time-Sequence Nets. These models try to effectively allow for the modelling of concurrent and asynchronous execution of the different cases (i.e. multi-threading). However, we see that a Petri-net model can effectively allow for the modelling of these features in a small-scale workflow situation. Another commonly-used approach for workflow modelling is the Activity Diagrams and other Unified Modelling Language (UML).

The modelling techniques above are challenged in modelling the dynamic aspect of workflow and cannot give a clear indication of where the dynamic is allowed, when changes occur and how the organisation can adapt the changes Just-In-Time. Another issue is that these modelling techniques model only one aspect of organisational workflow, and sometimes have too low a level of representation and they are basically not applicable at the conceptual level of development of complex organisational workflow systems. In these complex systems, it is necessary to model the workflow at a higher level of granularity that involves many sub-workflow components and workflow processes, their interfaces, interaction and relationships.

Considering all these modelling techniques, we need an approach that can effectively model object life cycles while the rest are directed at modelling the inter-object dynamic aspects. Of these, the last two are the most effective at capturing multi-threaded, asynchronous systems.

The dynamics in the workflow are difficult to model in any existing approaches. Dynamics of the workflow are listed below:

<u>Traditionally-defined Dynamic Aspects of workflow are as follows:</u>

1. Concurrency
2. Asynchronous execution
3. Flexibility to accommodate changes
4. Exception handling
5. Adaptability

Existing techniques in the literature can only partially, not fully, address the Concurrency (performance of different activities at the same time); the Asynchronous execution (not occurring at the same time or not having the same period) (Object Management Group. 1999); lack of flexibility to accommodate changes (unpredictable situations) (Casati, F. 1998); exception handling and adaptability to new changed environment (Jensen, K., 1992).

<u>Modern view of Dynamic Aspects of workflow are as follows:</u>

1. Concurrent Real-Time Process Modelling
2. Parallel Asynchronous execution
3. Inter-dependency relationships modelling between organisations and workflow tasks
4. Real-time Exception handling
5. Large-scale networked community workflow modelling

Most current approaches model one aspect of the system such as a partial workflow or sometimes are at a level too low for representation and they are basically not applicable at the conceptual level of development of complex systems. What one needs is an approach at 'chunking' the system to increase the granularity at which the original system is visualized and then to express this 'chunked' high granularity system in a semiformal representation that reduces ambiguity. The necessity for modelling the system at a higher level of granularity has increased with the appearance of large, complex, real-time systems that involve many processes operating on several different processors connected together through a network.

The objectives of this research are to develop an integrated modelling approach to help capture the complexity of the extended enterprise or community of heterogeneous organisational processes and to produce a uniform representation of the collaborative workflow for extended enterprise. The workflow design methodology will support the development of reconfigurable workflow information systems. The improved workflow modelling techniques and methodology will help to manage the interdependencies of the workflow components and establish interfaces between the components for coordination and integration and to reduce high dynamic risks of the workflow changes for extended enterprises.

The difficulties in the collaborative workflow modelling are associated with the community-based collaborative environment. Traditional workflow modelling and workflow software usually only work under the one policy, one portal, and one business rule and they usually used within one organisation. However, this is not the case in the collaborative community; where each party has their own policy, their own software, and their own business rules. In order for the community to work successfully, there should be another neutrally defined policy and workflow over and above each individual policy of each organisation. Can we develop a collaborative strategy and solutions powered by IT that help all the parties in the collaborative community? This thesis is trying to seek the answers.

2.18 CRITICAL REVIEW OF EXISTING WORKFLOW MODELLING APPROACHES

In this section, we give an overview of the strengths and weaknesses of the existing workflow techniques and approaches.

2.18.1 General Strengths

The key issues discussed in Aalst (1998) regard workflow modelling that is accurate and can adequately handle dynamic changes. Dynamism in a workflow model c relates to its flexibility, so that it can respond to the dynamic changes and still maintain the correctness of the representation of the workflow. This correctness is distinguished from syntactic and semantic correctness.

Syntactic correctness refers to the minimal requirements that any workflow should satisfy. It is relevant to both the structure of the workflow and the dynamic behaviour, e.g. to avoid potential deadlocks and live-locks.

Semantic correctness deals with similarities between the capabilities of the old workflow and the capabilities of updated workflow. Dynamic Change means that the changes are made while the system is executing.

In general, a workflow is considered as a collection/ combination of states and transitions that make up a process. Each workflow consists of configurable states and transitions that must be followed from the time an issue or feature is opened to the time it is closed. Each sequence of activities or transactions has to be executed in accordance with the business process of the organisation at hand.

The use of a workflow language for representation, analysis and design has led naturally to the need for computer support. A modelling system provides facilities for creating and browsing a representation model, for applying various algorithms to an analysis model and for collaborative interaction and information archiving for design models.

Existing workflow modelling techniques have created solutions to the problems of expandability, maintainability and specialization of workflow software systems. The intrinsic workflow software is based on the Object-component based model capable of handling inheritance relationship, encapsulation and polymorphism, and dynamic binding that are part of business processes.

2.18.2 **General Weaknesses**

There are various causes of failures in workflow systems [WS97]. Components of the workflow systems, the workflow infrastructures and tasks in the workflows are subject to failures during the system's runtime. In general, we can broadly classify the runtime workflow failures as Task Failures, Infrastructure Failures and Workflow Management Failures:

- **Task Failures:** these failures comprise various failures during a task's execution. Task failures can be further divided into two types: System Failures and Semantic Failures. *System failures* of a task are generally caused by the system environment in which the task is being performed. Reasons for system failures are various. System crashes, process deadlocks or machine malfunctioning could lead to the failure of the task. *Semantic failures* of a task are the logical exceptions raised by the task during the execution time. These failures are closely tied to the semantics of a task. For example, an exception may be raised in the hotel reservation task if the hotel rooms are full and the task user needs to handle the failure (either cancel the reservation or make a reservation in another hotel). Semantic failures are more common than the system failures in a workflow task.
- **Infrastructure Failures**: These failures result from the underlying infrastructures that support the WFMS communications. Runtime components in a workflow management communicate with each other through different infrastructures: intranet, Internet, mobile or Web. There are many causes of communication failures: for example, failure of an intranet, Internet, mobile or Web server on the network, network connection interruptions, network congestion, or a server crash, etc. Communication failures usually cause data transfer interruption, halting or long waiting of some system components, and

eventually may lead to abnormal termination of the workflow executions. Proper actions should be taken by the workflow modelling to address the infrastructure failures.

- **Workflow Management Failures**: These failures occur when one or more of the workflow management components, such as workflow schedulers or task managers, fail during the system runtime. System components are typically running as system processes or threads (lightweight processes) and they are subject to encounter failures. Many reasons may lead to the failure of system components: a computer failure (system crash), memory leaks, disk failures, an electric power shortage, human mistakes or system forced shut-downs, etc. System failures usually cause severe problems. They might cause the abnormal termination of some of the workflow tasks, part of or the entire workflow instance, or more severely the entire WFMS will crash if a proper failure recovery is not carried out immediately.

Current support for business processes usually focuses on either supporting the coordination aspect of a usually asynchronously executed business process by individuals or on providing communication or cooperation support for groups dealing with more fluid, ill-defined processes.

Since the early 1990s, several vendors have offered general-purpose workflow management systems. However, workflow systems today are often built in the same way as traditional application systems. That is, the finished products are targeted at definite scenarios and not designed to cope with a rapidly and dramatically changing environment. The problems with current workflow management systems are:

- The lack of real standards combined with a large scale of collaborating parties has created a scattered landscape where customers are reluctant to invest in workflow products. The numerous workflow management systems on the market today are based on different paradigms and offer contrasting functionalities.
- Most of the workflow management systems on the market today are unable to model the dynamic inter-dependent relationships.

2.18.3 **Critical Review of the Existing Approaches**

The key challenge is to develop a conceptual modelling of workflow and workflow components so that it incorporates a dynamic model that can deal with changes. This poses the question: how can the dynamism and flexibility of workflow components be modelled so that when the model is changed, the system can adapt the change quickly? Should the factors that caused the change be modelled? As the literature survey above indicates, the super-workflow components and sub-workflow components and their relationship, interaction and control aspects can be modelled, but are not practical in the real-world sense as the samples chosen are only for simple cases. The above surveyed approaches and methodologies have been used in industry including the well-known Petri-nets technique to model a workflow. Other methodologies that have been used include event-driven models, state event and action rules as well as tasks, or activities. However, a key issue is that these approaches have not been used in a large and complex multi-, inter-, and heterogeneous collaborative environment. The techniques proposed so far cannot scale up, and have not addressed the "dynamic" changes issue. A workflow model must effectively allow for the modelling of dynamic, concurrent and asynchronous execution of the different cases (i.e. multi-threading). However, of the models proposed above, only the Petri Net model effectively allows for the modelling of these features. Another methodology that researchers have begun to use to model a workflow is the activity diagram of Unified Modelling Language (UML) (Dellarocas C. and Klein M 2000, Denning, P.J. 1994).

Several other techniques have been introduced in the literature for modelling the dynamic aspects of systems including:

State Diagrams. The basic elements are rounded boxes representing the state of the object and arrows indicating the transition to the next state. The activity section of the state symbol depicts the activities that the object will be doing while it is in that state.

Sequence Diagrams model business processes regarding their behaviour in time. They focus on *when* the individual objects interact with each other during execution and, therefore, essentially include a time-line. Sequence diagrams consist of an actor that can start the message chain, an object which receives and sends messages, an arrow that indicates a message link between objects.

Use Case Diagrams: Use cases are used during the analysis phase of a project to identify and partition system functionality. They separate the system into *actors* and *use cases* (Anastassia. A, et al. 1998). Actors represent roles that are played by users of the system. Those users can be humans, other computers and pieces of hardware or even other software systems. The actors are drawn as little stick figures. Use cases describe the behaviour of the system when one of these actors sends one particular stimulus. The use case itself is drawn as an oval.

Petri-nets: Petri-nets are a formal and graphically appealing language that is appropriate for modelling systems with concurrency. As a graphical tool, Petri-nets can be used as visual-communication aids similar to flow charts, block diagrams and networks. In addition, tokens are used in these nets to simulate the dynamic and concurrent activities of systems; Petri-nets provide a means of estimating the time a system will take to proceed from an initial state or set of conditions to the desired final state. It consists of *places, transitions,* and *arcs* that connect them. *Input arcs* connect places with transitions, while *output arcs* start at a transition and end at a place.

Activity Diagram: An activity diagram represents the business and operational workflows of a system. It is a diagram that shows the activity and the event that causes the object to be in the particular state and talks more about transitions and activities causing the changes in the object states. It consists of an 'Initial Activity'. Initial Activity shows the starting point or first activity of the flow, denoted by a solid circle. This is similar to the notation used for Initial State. Initial Activity is represented by a rectangle with rounded (almost oval) edges. Decisions are similar to flowcharts; a logic where a decision is to be made is depicted by a diamond, with the options written on either side of the arrows emerging from the diamond, within box brackets. A Signal is when an activity sends or receives a message. Signals are of two types; Input Signal (message receiving activity) is shown by a concave polygon and an Output Signal (message sending activity) is shown by a convex polygon. Concurrent Activities: Some activities occur simultaneously or in parallel.

Such activities are called concurrent activities. Final Activity: The end of the Activity Diagram is shown by a bull's eye symbol, also called a Final Activity.

Of all these modelling techniques, the first two are effective for modelling object life cycles while the rest are directed at modelling the inter-object dynamic aspects. Of these, the last two are the most effective at capturing multi-threaded, asynchronous systems. After research analysis, several weaknesses in these existing workflow techniques were found. They are:

1. Concurrency (performance of different activities at the same time) [14]

2. Asynchronous execution (not occurring at the same time or not having the same period) [14]

3. Lack of flexibility to accommodate changes (unpredictable situations) [9]

4. Exception handling [13]

5. Adaptability to new changed environment [13]

However, in their current use, most of these approaches model one aspect of system like partial workflow or sometimes are at a level too low for representation and they are basically not applicable at the conceptual level of development of complex systems. What one needs is an approach that "chunks" the system to increase the granularity at which the original system is visualised and then to express this "chunked" high granularity system in a semi-formal representation that reduces ambiguity. The necessity for modelling the system at a higher level of granularity has increased with the appearance of large, complex, real-time systems that involve many processes running on several different processors connected together by a network.

The large-scale complex collaborative workflow modelling is necessary because the global trend towards the networked economy and virtual corporations and e-commerce, and the increasing global networking of economies is real and will accelerate. Enterprise information systems using workflow technology will play an increasingly critical role in providing a competitive edge to organisations in the networked economy. The issue here is that the networked economy is very dynamic.

This means that the actual processes of a case will be much more variable than the processes specified at design-time. These are the aims of this thesis.

2.19 CONCLUSION

In this chapter, we give our review of the literature on the existing workflow modelling techniques, and express the need for a large-scale collaborative workflow modelling tools to help managers or senior executives to understand the complexity of today's dynamic business environment. The collaborative workflow systems and techniques evolve due to the global acceleration towards virtual corporations, e-commerce, Internet technologies, and the increasing global networking of economies. Collaborative Enterprise information systems using collaborative workflow technology will play an increasingly critical role in providing a competitive edge to any organisations in the networked economy.

Chapter 3 - Problem Definition

3.1 INTRODUCTION

Whether the economy is strong or weak, competition is fierce. Changes come faster in this rough business environment (Cruz, S. M. S., Campos, M. L. M., Pires, P. F. & Campos, L. M., 2004). causing the business process model to be dynamic and complex. However, one has to manage it so the efficiency of business processes is maximized. Workflow modelling offers methods and techniques to achieve this and allows a company to deliver its promises. As the workflow paradigm continues to infiltrate organisations that need to cope with complex and growing business operations, the workflow system will become a fundamental building block. Therefore, workflow modelling tools and methods are of the utmost importance for leaders of a company in the design and re-design of business processes and management processes and the development of workflow systems to support the collaborative workflows.

In the last chapter, we presented an overview and review of the existing workflow modelling techniques, and in this chapter, we describe the challenges in collaborative workflow modelling and the issues to be dealt with in this thesis, followed by a proposal of the solutions.

3.2 FACTORS THAT IMPACT ON THE WORKFLOW CHANGES

According to Alonso, Agrawal, Abbadi, and Mohan 1997, there are basically two important factors which introduce the need to support dynamics in a workflow management system. These factors are:

3.2.1 **The Rapid Changing Environment**

Business activities and environments, as well as many engineering branches in general are highly dynamic and subject to constant evolution. As the business process is increasingly dynamic and the competitiveness among companies is growing so rapidly, re-design and optimization of existing business processes becomes more of a crucial factor in most organisations in order to gain better efficiency and effectiveness in the rapidly changing environments. In between radical re-designs, business processes often have to be adjusted over and over again. In fact, instead of frequent radical re-designs, the final goal is to constantly improve the business process by evolutionary redefinition.

3.2.2 **The Fast Growing Technologies**

As a result of technical advances, software systems are confronted with the need to evolve.

A critical challenge for workflow management systems is their ability to respond effectively to changes. Changes may range from momentary (ad-hoc) modifications of the process for a single customer to a complete restructuring of the workflow process in order to improve efficiency. Today's workflow management systems are ill-suited to deal with change; they typically support a more or less idealized version of the preferred process.

Technical advances often lead to system reconfiguration because of the replacement and updating of software components, the addition of new components or a change in component interface. "Peer-to-peer computing is the next great Internet-enabling technology. Not since the first demonstration of a World Wide Web browser has the true potential of the Internet been so apparent," said Rob Hegarty, Director of TowerGroup's Investment Management practice and author of the research. "TowerGroup expects widespread adoption of P2P technologies in all facets of financial services, particularly in investment research and electronic marketplaces. As P2P technology becomes more prevalent and accepted, it could go so far as to usurp the plethora of B2B exchanges."

A major concern of workflow technology is to model business process logic properly and provide suitable support for its execution. Workflow technology can be fully exploited when predictable and repetitive processes are executed. Unfortunately, real-world business processes are unpredictable. In this era, the competition between vendors is so high that fast response to changed market requirements is mandatory in order to stay in business. For instance, the growing interest in e-commerce among the companies has made them change the way they are doing business.

3.2.3 **Decisions That Cause Workflow Changes**

These changes may be structured or unstructured in nature; from a certain moment in time, the workflow changes for all new cases that arrive in the system. Changes are the result of a new business strategy, re-engineering efforts, or a permanent alteration of external conditions. Management typically initiates evolutionary change to improve efficiency or responsiveness, or it is forced by legislation or changing market demands. An example of such change is the change from a four-year curriculum at a university to a five-year one.

Another problem of change is that it typically leads to multiple variants of a process. In the context of 'flexibility of adoption', the terms 'version' and 'variant' become most important. For evolutionary changes, the number of variants is limited. In fact, if all cases are transferred directly after a change, there is just one active variant. However, if the 'proceed' way is used or transfer is delayed, there are multiple active variants. More troublesome are the situations where most of the flow time of cases is long and changes occur frequently.

3.2.4 **Ad-Hoc Requirements and Growing Demand**

This kind of change occurs only on an individual basis. It affects only a single case or selected group of cases. The changes are the result of an error, a rare event or a special demand from a customer. Moreover, an exception can often be triggered for this ad-hoc change. A typical example of an ad-hoc change is to skip a task in the case of an emergency situation. This change is often initiated by some external factor. However, a problem related to ad-hoc changes is deciding what kinds of changes are allowed and it is almost impossible to predict all the possibilities.

Ad-hoc changes may lead to a situation where the number of variants may be of the same magnitude as the number of cases. To manage a workflow process with different variants, it is desirable to have an aggregated view of the work in progress. It is of the utmost importance to supply the manager with tools to obtain a condensed but accurate view of the workflow process. The current workflow management today deals with only one aspect of the organisation, such as operations, and assumes that everything is well-defined and is not subject to change.

3.3 TYPE OF CHANGES IN WORKFLOW

Typically, there are two types of ***changes*** with respect to routing of the cases, or in other words, the flow of work (Aalst, W.M.P. van der; Basten T.; Verbeek, H.M.W.; Verkoulen, P.A.C.; Voorhoevoe, M.,1999). These two types of changes are ad-hoc changes and evolutionary changes.

3.3.1 **Ad-Hoc Change**

This kind of change occurs only on an individual basis. It affects only a single case or selected group of cases. The changes are the result of an error, a rare event or a special demand from a customer. Moreover, an exception can often be triggered for this ad-hoc change. A typical example of an ad-hoc change is the omission of a task in case of an emergency situation. This change is often initiated by external factors. In general, it is not necessary to change the workflow definition because the change will most probably not happen in this situation again. However, there is a problem related to ad-hoc changes: deciding what kind of changes are allowed; in fact, it is almost impossible to predict all the possible changes. For this kind of change, we could classify it, in terms of when it could happen, into two types (Aalst, W.M.P. van der; Basten T.; Verbeek, H.M.W.; Verkoulen, P.A.C.; Voorhoevoe, M.,1999):

- Entry time

The routing definition is frozen the moment the processing of the case starts. In other words, no changes are allowed during the processing.

- On-the-fly

Changes are allowed at any moment, i.e., the process might change while the case is being handled by the system. Ad-hoc on-the-fly changes allow for self-modifying routing definition.

3.3.2 **Evolutionary Change**

These changes are structural in nature; from a certain moment in time, the workflow changes for all new cases that arrive in the system. The change is the result of a new business strategy, re-engineering efforts, or a permanent alteration of external conditions. Management typically initiates evolutionary change to improve efficiency or responsiveness, or it is forced by legislation or changing market demands. An example of such change is the change from a 4-year curriculum at a university to a 5-year one. Evolutionary change always affects new cases but it may also influence old cases. There are three different ways to deal with existing cases:

- Restart

In this way, all existing cases are aborted and restarted. At any time, all cases use the same routing definition. For most workflow applications, it is not acceptable to restart cases because it is not possible to rollback work or it is too expensive to flush cases.

- Proceed

In this way, each case refers to a specific version of the workflow process. Newer versions do not affect old cases. Most workflow management systems support such a versioning mechanism. A disadvantage of this method is that old cases cannot benefit from an improved routing definition.

- Transfer

Existing cases are transferred to the new process; i.e., they can directly benefit from evolutionary changes. Both for ad-hoc and evolutionary change, there are three ways in which the routing of cases along tasks can be changed.

- Extend

Adding new tasks, which are executed in parallel, offer new alternatives, or are, executed in-between existing tasks.

- Replace

Another task or a sub-process replaces a task, or a complete region is replaced by another region.

- Re-order

Changing the order in which tasks are executed without adding new tasks, e.g. swapping tasks or making a process more or less parallel. Note that there exists a strong relationship between ad-hoc changes and evolutionary changes. If ad-hoc changes are to be made permanent, we are then confronted with the problem of evolutionary changes. There are three factors, which could be the origin of changes:

- Exceptions

Many factors may generate exceptions that should be handled like incompatibility between the product and its recorded information.

- Technical

Appearance of new tools or techniques that should be used in workflow could lead to changes in the workflow itself.

- Legislative

This factor is related to changing the environment. For example, new laws in a country could add more constraints to the reusable percentage of a product.

3.3.3 **Structural Flexibility**

There are many interpretations of flexibility. This section is focused on flexibility of the workflow management applications. In paper (Horn, S.; Jablonski, S. 1998), two aspects of flexibility can be identified that have to be supported by the workflow management application: The user should have the freedom to choose between different execution paths if necessary. This requirement arises because it is not always possible or desirable to prescribe in detail the sequence of control and correction steps. It must be possible to change the workflow management application during Just-In-Time and sometimes at runtime. This is because it is almost impossible to identify all control and correction steps and the mapping of the real-world scenario to workflow type is prone to error. In terms of these two aspects, Stefen Horn et al., identified two kinds of flexibility:

- *Flexibility by selection.* This type of flexibility is useful when a high number of execution paths for a workflow are either known and/or anticipated. Implicitly and explicitly, these execution paths are described by the workflow type specification.

- *Flexibility by adoption.* The drawback of 'flexibility of selection' is the limitation imposed by the requirement of anticipation that has to be included in the workflow type specification. In some application scenarios, this might be not sufficient and even more flexibility might be required. Thus, flexibility by adaptation adds one or more execution paths.

3.3.4 **Processes Change**

'Dynamic' means that changes are made while the system is executing. The ability to dynamically modify a process definition, the associated data, and behaviours associated with objects, and the set of views into the process while in progress, is crucial for workflow process execution and evolution over time. A set of 'data or information' represent a 'case' in a workflow and a 'behaviour' initiates a 'event' that creates workflow activity. A workflow cannot be fixed in the current business environment; it has to be more closely suited to changing requirements, availability of resources, and the applicability to the current work content. As mentioned in the previous section, there are three ways to deal with running cases after a structural process change:

- restart the event
- precede the event
- transfer the event

There are some problems related to dynamic change that need to be considered. These include the fact that it is not acceptable to pause or shutdown the system and transfer all cases or events to the new workflow generated and then restart the system. Cases or events should be transferred while the system is running. Dynamic change may introduce deadlocks and live-locks. All running cases have to be modelled and analysed after a new workflow has been generated.

3.3.5 Exceptions and Change Management

Workflow change may occur on an individual basis or group basis. It may affect a single case or a selected group of cases. The changes are the result of an error, a rare event or a special demand from customer. Moreover, an exception can often be triggered for this ad-hoc change. A typical example of an ad-hoc change is to omit a task in the case of an emergency situation. This change is often initiated by some external factor. In general, it is not necessary to alter the workflow definition because the change is unlikely to happen in this situation again. However, a problem related to ad-hoc changes is deciding the kinds of changes that are allowed and it is almost impossible to predict all the possibilities. For this kind of change, we could classify it in terms of when it could happen, into two types.

- Entry time. The routing definition is frozen the moment the processing of the case starts. In other words, no changes are allowed during the processing.

- On-the-fly. Changes are allowed at any moment, i.e., the process might change while the case is being handled by the system. Ad-hoc, on-the-fly changes allow for self-modifying routing definition.

Ad-hoc changes may lead to a situation where the number of variants may be of the same magnitude as the number of cases. To manage a workflow process with different variants, it is desirable to have an aggregated view of the work in progress [Aalst, W. et al. 1999]. Note that in a manufacturing process, the manager can gain a good impression of the work in progress by walking through the factory. For a workflow process handling digitised information, this is impossible. Therefore, it is of the utmost importance to supply the manager with tools to obtain a condensed but accurate view of the workflow process. The workflow management of today deals with only one aspect of the organisation, such as operational, and assumes that everything is well defined and is not subject to change.

Business activities and environments, including many industrial branches, are highly dynamic and subject to constant evolution. As the business process is increasingly dynamic and the competitiveness among companies is growing rapidly, re-design and optimization of existing business processes becomes more of a crucial factor in most organisations. This enables them to apply better efficiency and effectiveness in their rapidly changing environment. Besides radical re-designs, business processes often have to be adjusted repeatedly. Instead of frequent radical re-designs, the final goal is to constantly improve the business process by evolutionary redefinition. Some of the factors identified by us are flexibility, dynamism, Strategic Decisions that Cause Workflow Changes, Ad-hoc Requirements and Growing Demand for Improvement that Cause Workflow Changes, Rapid Technological Growths and Exceptional Events. Each of these is explained in detail in the following paragraphs.

In order to have a dynamic workflow management system, the system should be able to handle dynamic changes. Once the workflow model has changed, the model must be analysed or validated to ensure the model still reflects a correct business process. As there could be many versions of a workflow model, a method is needed enabling them to be viewed collectively. Generally, two concepts in workflow are seen: Flexibility and Dynamism.

3.4 DYNAMIC BEHAVIOURS ISSUES

Dynamic change can be viewed as an exception of occurrence of some unexpected or abnormal event. The exception can result from such sources as inconsistent data, divergence of tasks from underlying workflow model, unexpected contingencies and un-modelled change in the environment (Aldowaisan T.A. and Gaafar L.K.. 1999). In most cases, exceptions are undesirable because they generate additional complications and work. If a workflow management system provides an exception handler, it is possible to specify the actions to be performed in order to respond to certain exceptions. However, often the humans participating in the process are the real exception handlers because it is not possible to pre-specify all possible exceptions. Some researchers have classified exceptions in terms of their dimension. Source dimension classifies where an exception occurs(Anastassia. A, et al. 1998). Type dimension classifies the knowledge of the workflow management system on a particular occurrence of an exception (Anastassia. A, et al. 1998). Consequence dimension classifies the impact of the exception to the workflow model, i.e. the kinds of changes (Aldowaisan T.A. and Gaafar L.K.. 1999).

There are few types of exception; here we discuss them in detail:

3.4.1 **Expected Behaviour in Dynamics**

These kinds of behaviour are already anticipated and offer predictable deviations from the normal behaviour of the process.

Examples of this kind of behaviour:

- In a travel reservation process, the customer cancels the travel reservations request.

- In a car rental process, an accident occurs to a rented car, which is not available for subsequent rentals.

Fabio Casati categorizes more broadly expected exceptions into four classes according to the event that causes them:

- Workflow exceptions are raised in correspondence with the start or completion of tasks and workflow instance, and are therefore synchronous with the progression of the workflow.

- Data exceptions are raised by modifications to workflow relevant data.

- Temporal exceptions are raised at the occurrence of a given timestamp, periodically, or after a defined interval has elapsed since a reference event.

- External exceptions are activated by external events, explicitly notified to the workflow engine by agents or external applications.

3.4.2 **Unexpected Behaviour in Dynamics**

These kinds of behaviours or exceptions, on the contrary, require human intervention since they are unanticipated and unpredictable. Unexpected behaviours occur so often because the workflow modelling phase is so complex and often cannot accurately capture the dynamism of the system, and because the characteristics and requirements of the business process may change over time, due to, for instance new laws, new business objectives, or technological innovations.

3.4.3 **External and Internal Dynamics**

External Dynamics arises from external components included in the workflow management system such as the operating system, DBMS, software applications, machines and equipment, etc.

Internal Dynamics relates to the workflow system itself, and includes issues such as the inability to find a resource required for executing a task, missing a deadline or running over budget, special-case outcomes from a finished task, etc.

3.4.4 **Noise and Idiosyncratic in Dynamics**

Noise is able to be tolerated by the process or can be safely ignored and still produce a satisfactory result. There is no need to change the workflow model. However, idiosyncratic behaviours are relatively unique to a specific case or set of cases. If this exception behaviour happens, we need to change the case to a specific instance of workflow; however, the workflow type remains the same.

3.4.5 **Evolutionary Behaviour**

Evolutionary behaviour changes the overarching workflow model. It is this type of change that produces evolution of dynamics over time, driving long-term change in the workflow process.

3.5 ISSUES TO BE ADDRESSED IN THIS THESIS

The issues to be addressed in this thesis are the modelling issues related to the type of workflow, namely: intra-, inter- and heterogeneous workflow environments. These modelling issues are:

- Time and real-time aspects
- Parallel and synchronized behaviour
- Inter-dependent dynamic relationships

Many researchers have tried to address these issues in order to handle dynamic changes. The strengths and weaknesses of the existing techniques have been reviewed in the last chapter and it was concluded that they are mainly good at modelling small portions of the workflow, and not the full workflow in a collaborative environment. We note that the workflow model may evolve due to heterogeneous participation of the agents in the workflow. If the workflow is changed, the model must be analysed or validated to make sure the model still reflects a correct business process. We need a method to view the model change in a comprehensive manner. The following sections explain each issue in detail.

The conceptual view of collaborative workflow management components helps with the design and development of a dynamic model and workflow modelling techniques so as to deal with changes. However, how can a workflow framework be developed for a collaborative enterprise? How can the dynamism of workflow components be modelled so that when the model is changed, the workflow system can adapt to the change quickly? What are the factors that caused the change in an extended enterprise? Can we make super-workflow components and sub-workflow components define their relationship, interaction and control aspects so that the workflow management system will be more dynamic? How dynamic can a workflow management system be made? How can we define the level of flexibility and type of changes? How can we construct a formal method that can be applied to an extended enterprise so that the collaborative workflow management system can be adapted to the changes?

3.5.1 **Time and Real-Time Aspects**

'Dynamic' refers to the changes that are made while the system is in runtime and in execution. The ability to dynamically model a changed process, the associated data, behaviours associated with objects, and the set of views into the process, at the time it is in progress, is crucial for workflow process management and workflow evolution control over time. This allows the workflow to better-fit changing requirements, availability of resources, and the applicability to the current work content. The previous section mentioned three ways to deal with running cases after a structural process change: restart the case, proceed with the case and transfer the case. Restarting cases causes no real difficulties except that it is often difficult to roll back the tasks that have already been executed. Proceeding with the cases causes no problem either. In fact, it is the only approach that is supported by most of commercial workflow management system. Transferring cases is the only policy that causes serious theoretical and practical problems. Modelling the time and real time also captures the old behaviour in a new process, e.g. it transforms an old behaviour to a new, improved version of the workflow process.

There are some problems related to time and real-time modelling, largely related to capturing the change, which need to be considered. These include:

- It is not acceptable to pause or shut down the system and transfer all cases to the new workflow type specification and the restart the system. Cases should be transferred while the system is running.

- It is not always possible to transfer a case.

- Dynamic change may introduce deadlocks and live-locks.

- All running cases have to be patched after applying a new workflow type.

3.5.2 **Modelling Parallel Synchronous and Asynchronous Behaviours**

There is an extensive history in discrete system modelling language development, ranging from computer simulation languages to iconic visual languages. Many of these languages, including workflow-modelling languages, adopt a data/control flow perspective. A workflow model represents how a unit of workflows from one processing steps to another. Thus, a workflow language contains constructs to define a set of steps that represent units of work. Two types of workflow modelling language have been identified by Novak, B., (2006). A sequential computation language for modelling is to provide an interpretation for each step, and a coordination language to define how the workflows among these steps.

The fundamental purpose of a representation computation language is to enable one person to describe how a step is accomplished for the benefit of other human readers. This type of computation language concentrates on features that can be used to provide clear and intuitive explanations.

Coordination language for modelling specifies how a case moves from step to step. This is an identifying characteristic of a workflow language. The coordination language is embellished to explicitly represent disjunctive and conjunctive control flow. Disjunctive control flow represents the situation where a case may flow from step X to step Y or to another step Z (but not both). Conjunctive control flow represents the situation where both step Y and Z are to be executed after X has completed. In general, a workflow coordination model can be defined as a directed graph (N, E) with a node set N representing individual steps in the procedure and an edge set E representing the coordination structure among the tasks.

Two kinds of approaches can be used in workflow modelling.

High-level workflow modelling approach: It is based on graph- or net-based concepts and defines workflows by drawing ‘bubbles and arcs’. The advantages of this approach lie in the modelling of a workflow at a high level of abstraction, in the graphical visualisation of workflows and in the good support for workflow analysis.

These strengths are also fundamental for human intervention in order to support dynamic change. The disadvantage of this approach is that neither dynamic control flows nor dynamic data flow, in particular between running tasks, are supported.

Low-level workflow modelling approach: It is based on reactive rule-based formalisms; fine-grained inter-task state dependencies can be specified and enacted. However, any workflow models modelled by this approach would be difficult for humans to understand, and hence, inadequate for human intervention and dynamic change. We have developed a UML-based extended activity graph to represent dynamic workflow model the fundamental concepts of which are a worklet, action, actor, agent, exception handler, and notation system. We intend to continue to refine this approach in conjunction with Petri-net to enhance and incorporate synchronous and parallel processes.

An action can be viewed as a big object that contains other objects. It is represented as a lozenge shape, but it has other rectangles above and below it. Figure 3.1 shows the notation. Note that, if the value of actor is none, it means that the action is an automatic one; otherwise, it is a manual one.

3.5.3 **Modelling the Inter-Dependent Dynamic Relationships**

Most other authors of workflow generally model only the operational aspect of a business process through analysis. It has been found that there are many workflow components within an extended enterprise and these workflow components interact with each other to achieve the extended enterprise goals and objectives and therefore decompose the collaborative workflow into the following levels:

A collaborative workflow operation is usually measured by its performance and by the volume of its output. The operational workflow is the main source of value generation for the organisation. It can further be divided into the following: Operational control workflow and Production workflow.

Collaborative workflow can be divided into four subcomponents: Administrative control workflow, Accounts management workflow, Human resources management workflow, and Customer relations workflow. Administrative control workflows are involved in making decisions and prioritising and scheduling tasks. The administrative task workflow is measured by its efficiency.

3.6 Choice of Research Method

The thesis's objectives are to develop Collaborative Workflow Modelling method Based on Activity Diagrams, Coloured Petri-nets and System Dynamics for complex collaborative business environment. In order to carry out this study, the author needs to follow a systematic, scientific approach, to ensure the modelling approach is scientifically sound and practically suitable. In this section, the author give an overview of existing scientific research methods and give a reason on why we choose a particular scientific based research method for this thesis.

There are two broad categories of research in information systems namely (*a*) science and engineering approach and (*b*) social science approach. **Science and engineering based research** is concerned with confirming their theoretical predictions. Galliers 1992 [148] particularly states that in the engineering field the spirit of 'making something work' is essential and has three levels: conceptual level, perceptual level and the practical level.

- Conceptual level (level one): creating new ideas and new concepts through analysis
- Perceptual level (level two): formulating a new method and a new approach through design and building the tools or environment or system through implementation
- Practical level (level three): carrying out testing and validation through experimentation with real world examples, using laboratory or field testing

Science and engineering research is expected to lead to new techniques, new architecture, new methodology, new devices or a set of the new concepts which together form a new theoretical framework. It also frequently addresses the questions not only of what problems need to be addressed but proposes a solution.

Social science research can be quantitative or qualitative research often through survey or interview processes. Quantitative research involves extensive data gathering usually using instruments such as survey and statistical analysis of this data in order to prove or disprove various hypotheses that have been formulated. Qualitative research frequently involves in-depth structured or semi-structured interviews that allow one to pursue particular issues of interest that may arrive during the interview. It does not normally involve a large sample of data and the information gathered may not be in a form that readily allows statistical analysis. A typical social science research approach, the use of survey forms, is to identify problems for more processing investigation to develop hypotheses. The goal of this research is to obtain evidence to support or refute a formulated hypothesis (Kaplan, B & Maxwell, JA 1994 [149], Audet, J & Amboise, G 2001 [150]. This research only tests or evaluates a method that is already produced from science and engineering research and to help researcher to understand people and social issues. This type of research method can imply how well the methodology is accepted or not accepted and sometimes may be able to give the reason. However, unlike engineering-based research, this type of research does not explain what a methodology should be or how to produce new methods for problem solving. Therefore, in this thesis, the author choose science and engineering based research methodology.

3.7 CASE STUDIES FOR COLLABORATIVE WORKFLOW MODELLING

Modelling is used for representation, analysis and design of a large, complex workflow environment. It naturally will be converted to an automated computer support. A modelling system provides facilities for creating and browsing a complex representation of structure and dynamics, for applying various algorithms to an analysis model and for collaborative interaction and information archiving for design models.

We will use the three following case studies and examples to illustrate our modelling approaches for the intra-, inter- and heterogeneous organisation collaborative workflow environments.

For intra- and inter-organisation workflows, we simulate Hong Kong Warehouse operations, and the industry partners include field-testing, evaluation and benchmarking in their current practices. Specifically, we take the example of Two Warehouse-Logistics Consortium in Hong Kong and Sydney. The manager and staff will use both existing workflow techniques in parallel with our new proposed method. For the heterogeneous workflow environment, we will use WA-Port container movement as the case study. In order to understand the complexity of the workflow environment, we will carry out detailed interviews with managers and staff and in-depth case studies, and we will communicate our outcome of the proposed workflow technique and design method to our industry partners. We will use the prototype systems either through the simulation of the real-world business processes or through field studies to verify the proposed modelling methodologies.

- Case Study 1: Hong Kong Seapower Warehouse Logistics Operation, see Chapter 5-8

- Case Study 2: WA Port Container Operation, see Chapter 9-10

3.8 CONCLUSION

In this chapter, we provide a detailed study of dynamics in the workflow and collaborative workflow, and we analyse what are the factors, causes and impact on the workflow change. We then highlight the issues of behaviour changes in the dynamics environment, and this is followed by an explanation of the issues that this thesis has to address. We outline that these issues are to be addressed in the intra-, inter- and heterogeneous collaborative workflow environments. Finally, we give a brief outline of the case studies we are going to use to demonstrate out modelling techniques.

Chapter 4 - Body of Knowledge for Workflow and Collaborative Workflow

4.1 INTRODUCTION

In this chapter, we provide a comprehensive description of the body of knowledge on workflow and collaborative workflow. Workflow systems have emerged as a core business technology to support operations and productivity in any organisation. The collaborative workflow systems play central roles in multi- and distributed organisations who work cooperatively to achieve business outcomes in intra-, inter- and heterogeneous environment settings.

4.2 WORKFLOW

Workflow is defined as a computerized facilitation or automation of a business process, in whole or part. Workflow covers the automation of procedures where documents, information or tasks are passed between participants according to a defined set of rules to achieve, or contribute to, an overall business goal.

Workflow may be manually organised, but in practice, most workflow is normally organised with the assistance of an IT system to provide computerized support for the procedural automation..

The concept of workflow can be claimed to originate from the early days of office automation (Cerami, E., 2002). It started out as manual routing of folders through routing slips, and was further developed into electronic image-based and document centric systems. And now, it has developed into a general-purpose graphical workflow system. Now business and project managers, as well as other employees, can take advantage of a number of helpful tools, which ease the work of structuring, delegating and performing different tasks.

Workflow is part of a larger software development called *groupware* or *computer supported cooperative work (CSCW)*. These include technologies such as those proposed by Chang, E., (2000), Chen, Guanrong, and Xinghuo Yu, eds. (2003).

- Electronic mail
- Discussion groups
- Tele/video/desktop conferencing
- Collaborative writing
- Scheduling system or Personal Information Manager
- Document control systems
- Meeting facilitation
- Computer bulletin boards
- Workflow

Workflow, itself, incorporates many of the technologies mentioned above. A workflow system will normally integrate at least electronic mail, work scheduling and document control. It is expected that in the future, workflow systems will incorporate more of the technologies mentioned in the list.

There exist many different definitions of workflow, so it is difficult to choose the best. *The Workflow Management Coalition (WfMC)* is a non-profit international body for the development and promotion of workflow standards. Since its establishment in August 1993, it has grown to comprise over 100 members including workflow vendors, users and analysts. Their definition is as follows according to Christensen, J.H. (1994):

"The automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set procedural rules"

In addition to the formal definition presented above, some additional aspects of workflow normally required by the users can be mentioned. This is to give a better understanding of workflow, not to expand the definition further. It should be possible to:

- Pass documents, information and tasks not only from one participant to another, but also between groups of individuals. This also facilitates hiding the individuals behind a group, supporting the concept of *roles.*
- Track some or all aspects of the execution. This is of great help in evaluating the progress of a process or set of processes.

Workflow is also associated with Business Process Re-engineering (BPR), which is concerned with the assessment, analysis, modelling, definition and subsequent operational implementation of the core business processes of an organisation (or other business entity). Although not all BPR activities result in workflow implementations, a workflow model is often an appropriate solution as it separates the business procedure logic from its IT operational support, enabling subsequent changes to be incorporated into the procedural rules defining the business process. Conversely, not all workflow implementations necessarily form part of a BPR exercise; for example, implementations to automate an existing business procedure.

4.3 WORKFLOW MODELS

As the workflow paradigm continues to infiltrate organisations, managers need to cope with complex and growing business needs; the workflow models is derived from the workflow modelling, and is then realized by a workflow systems which is the fundamental building block of any business. Therefore, workflow, workflow modelling, workflow systems, tools and method are of the utmost importance for leaders of the company in the design and re-design of business processes, operational processes, management processes and the development of systems to support these processes.

A workflow model can be viewed as a simplified representation of a past, actual or future workflow process. Workflow modelling can be used to create workflow specifications based on the workflow process of a particular organisation. Such specifications will usually be used as input to a workflow management system. The use of workflow specifications has often been advocated by Bar-Yam B. (2004), Chen, Guanrong, and Xinghuo Yu, eds. (2003)] to reduce ambiguity and facilitate verification and analysis.(Bar-Yam B, 2004).

Being able to adapt quickly to a new situation usually involves quick re-modelling of the work performed in the business, something that is best done by the end-users themselves. They know best how the work was performed previously and how it will or should be performed now. As a result of this, flexible workflow systems must be designed so that the end-users can easily perform the modelling without expert guidance. This requires, among other things, a good graphical user interface combined with an understandable modelling language.

4.4 WORKFLOW MODELLING

A model is an abstract representation of a target phenomenon (Braha D. Minai, A.A, Bar-Yan 2006). A model aeroplane is an abstraction of a real aeroplane that represents the appearance of the real aeroplane. A PERT chart represents the order of steps in product design and manufacturing. A model represents a subset of the characteristics of the target system. Modelling is a process that constructs a subset representation or abstraction of a system that represents the target systems (Dami, S., Estubiler, J., Amiour, M.: (1996). Its aim is to increase an understanding of the system and to clarify the requirements so as to minimise the likelihood of misinterpretation of the original needs.

There is an extensive history in discrete system modelling language development, ranging from computer simulation languages to iconic visual languages. Many of these languages, including workflow-modelling languages, adopt a data/control flow perspective. A workflow model represents how a unit of workflows from one processing step to another. Thus, a workflow language contains constructs to define a set of steps which represent units of work. Two types of workflow modelling language have been identified by Braha D. Minai, A.A, Bar-Yan (2006): a sequential computation language to provide an interpretation for each step, and a coordination language to define how the workflows among the steps.

A workflow language allows a precise description of the workflow so that it allows a clearer understanding between different people reading the workflow description; coordination languages also allow explicit representation of conjunctive and disjunctive workflows. Workflow modelling can be either high level or low level. High level workflow modelling has a higher level of abstraction utilising graphical or net-based representation, while low level workflow provides fine-grained specification usually based on established rules.

The use of a workflow language for representation, analysis and design has led naturally to the need for computer support. A modelling system provides facilities for creating and browsing a representation model, for applying various algorithms to an analytical model and for collaborative interaction and information archiving for design models.

The fundamental purpose of a representation computation language is to enable one person to describe how a step is accomplished for the benefit of other human readers. This type of computation language concentrates on features that can be used to provide clear and intuitive explanations.

4.5 WORKFLOW MANAGEMENT

Workflow management is a technology that involves the automation of business processes. By controlling business processes, workflow management ensures that applications used in the business process are initiated and presents the necessary information to the right group or person at the right time. The end result is the creation of efficient, effective and manageable business processes.

Workflow management is a fast evolving technology being exploited by business in a variety of industries. Its primary characteristic is the automation of process involving a combination of human and machine-based activities, particularly those involving interaction with IT application and tools. Although it is most prevalently used within the office environment in staff-intensive operations such as banking, legal and general administration, it is also applicable to some classes of industrial and manufacturing applications such as logistics operations, medical applications etc.

4.6 WORKFLOW MANAGEMENT SYSTEMS

Workflow Management System (WFMS): “a system that defines creates and manages the execution of workflows through the use of software, running on one or more workflow engines, which is able to interpret the process definition, interact with workflow participants and, where required, invoke the use of IT tools and applications”.

A Workflow Management System is a system that provides procedural automation of a business process by managing the sequence of work activities and the required resources (people, data and applications) associated with the various activity steps. By enabling the creation of efficient, effective and manageable business processes, their use can result in significant time savings and can prevent delays inherent in supply chain transportation. When used in combination with document management systems, they can eliminate paper-based administrative procedures such as photocopying and the manual archiving, retrieval and distribution of documents.

A workflow management system allows one to design, sequence, and monitor extended business or industrial processes over a finite time horizon to carry out several interlinked activities. It includes process modelling, executing, re-engineering, monitoring and automation of workflow.

A workflow management system is one which provides procedural automation of a business process by managing the sequence of work activities and the invocation of appropriate human and/or IT resources associated with the various activity steps. An individual business process may have a life cycle ranging from minutes to days (or even months), depending upon its complexity and the duration of the various constituent activities. Such systems may be implemented in a variety of ways, use a wide variety of IT and communications infrastructure and operate in an environment ranging from small local workgroup to inter-enterprise.

A workflow management system is a generic information system that supports modelling, execution, management and monitoring of workflows. Such a system operates on a workflow specification, a description of the business processes in the organisation that should be supported. A workflow management system can be compared to a database management system: it is a generic system that operates on a schema definition of the (processes in the) organisation.

In Cruz, S. M. S., (2004) and David Neumann (2004) , workflow management systems have been categorized as follows:

- Design versus Runtime: In a design-oriented workflow system, the focus is on the creation, analysis and simulation of workflow process. Runtime-oriented system represents the engines that provide generic routing and tracking services to the applications.
- Mail- versus Database-driven: Mail-driven systems rely on electronic mail to route and present work to users. The simplicity of the systems makes them easy to handle and well suited for wide-area distribution, but they lack some qualities often needed. One such quality often missing is the ability to track the progress of the process or document. Database-driven systems do not have the same insufficiency. They rely on underlying database technology to drive the process, making it possible to keep track if the process. This ensures strong management and reporting capabilities.
- Document- versus Process-driven: Examples of document-driven systems are folder management and image routing systems. They are generally good for handling manual, paper-based procedures electronically. Processes-oriented systems model the work process as a sequence of steps, with data objects attached to each step. These can handle more complex workflows, but might be less intuitive for end-users in simple cases.

The most common uses of a workflow management system is to support business processes. Business processes have been a focus for the development of computer support for a long time. Over the past few years, more emphasis has been placed on the inherent collaborative nature of business processes carried out by organisations comprised of people (Denning, P.J. & Metcalfe, R.M., 1998 and Denning, P.J., 1994). In fact, collaboration is the main characteristic of workflow. In general, three aspects of collaboration can be distinguished(Dami, S., Estubiler, J., Amiour, M 1996):

- *Communications*. This refers to the basic ability to exchange information in any required form in the collaboration process between the parties involved.
- *Coordination*. This focuses on scheduling and ordering tasks performed by these parties.
- *Cooperation*. This focuses on actually performing the business process collaboratively.

4.7 BUSINESS PROCESS IN WORKFLOW

4.7.1 **Processes**

A process is a partially-ordered collection of activities with a specific purpose. A process can be a business process, an inter-organisational process, a development process, and the like.

4.7.2 **Business Processes**

A business process is any set of activities performed by a 'company' that is initiated by an event, transforms information, materials and/or business commitments, and produces an output [*Business Process Trends*, 2004].

A group of business activities is undertaken by an organisation in pursuit of a common goal. Typical business processes include receiving orders, marketing services, selling products, delivering services, distributing products, invoicing for services, accounting for money received. A business process usually depends upon several business functions for support, e.g. IT, personnel, accommodation. A business process rarely operates in isolation; i.e., other business processes will depend on it and it will depend on other processes (Jin Jing, Karen Huff, 1999).

4.7.3 **Business Rules and Workware**

Derek Miers (1996) proposed a new expression called *workware.* This is to replace what he thinks is an unfortunate tendency to focus too much on the ‘flow’ of workflow. Through this term, he hoped to emphasize the roles, business rules and objects, which are manipulated by the process.

Businesses rules enable an organisation to adapt to business processes in the complex business environment. Rules provide a guide to how change is to take place in the internal structure of the organisation and how the processes should be performed. Hence, the workflow system being utilised uses these rules to handle the changes. Many traditional production-based workflow systems have a problem coping with change since they have been designed for repetitive processes and not for rapid change. So, as a logical prerequisite, rules need to be developed to support such situations.

4.8 ADAPTIVE WORKFLOW

Adaptive workflow can be defined as dynamically adapting the control and data flow in the processes during runtime instances; it is generally an automated process.

Changes to the workflow can be either static or dynamic. Static changes are those changes made to the workflow while it is not being executed. Modifications can be made to various elements of the workflow such as the process, the available resources; moreover, changes can be made to the resource allocation mechanism. Dynamic changes are those changes made to the active instances of the workflow (Boley, H. 2006).

In the workflow literature, various categories of adaptability have been defined (Boley, H. 2006) such as *flush, abort, migrate, adapt,* and *build,* with each of these terms representing a respective increase in the extent to which the system adapts to change. In flush mode situations, all current instances are allowed to complete according to the old process model, but new instances are planned to follow the new model. For the other four modes, the existing, active instances of the workflow can be affected by the change. In the *abort* mode, the current active instances are aborted; in the *migrate* mode, the execution of the workflow continues while the new changes are integrated into the process; in the *adapt* mode, the process must be altered for individual instances in order to accommodate some exceptional cases, and in the *build* mode, the whole process can be rebuilt at runtime so that the appropriate process model that corresponds to the particular situation at hand can be created.

4.9 COLLABORATIVE WORKFLOW

A collaborative workflow is defined as the collaboration of a group of companies working together towards common goals. They can range from a small group of companies, project-oriented research teams, to widely dispersed industries with common interests. Effective use of collaborative workflow is now considered a vital element in the success of enterprises of all kinds. With advancement of B2B (Business to Business) and P2P (Partner to Partner) e-commerce (Alston, J., Hess, D. and Ruggieo, R., 2002), there has been an increasing tendency to set up consortia that represent several players in a given field. Such consortia consist of companies or organisations in a given field that get together and produce a single site or what appears to be a single site in order to increase traffic through the site compared to other competitors' sites and/or extend beyond their region of operation. Similarly, at the back-end, these companies need to have a back-end system which needs to be integrated to efficiently work towards meeting their consortium obligations (Figure 4.1). However, a mere enumeration of all workers, activities and artefacts does not quite constitute a process. We need a way to describe meaningful sequences of activities.

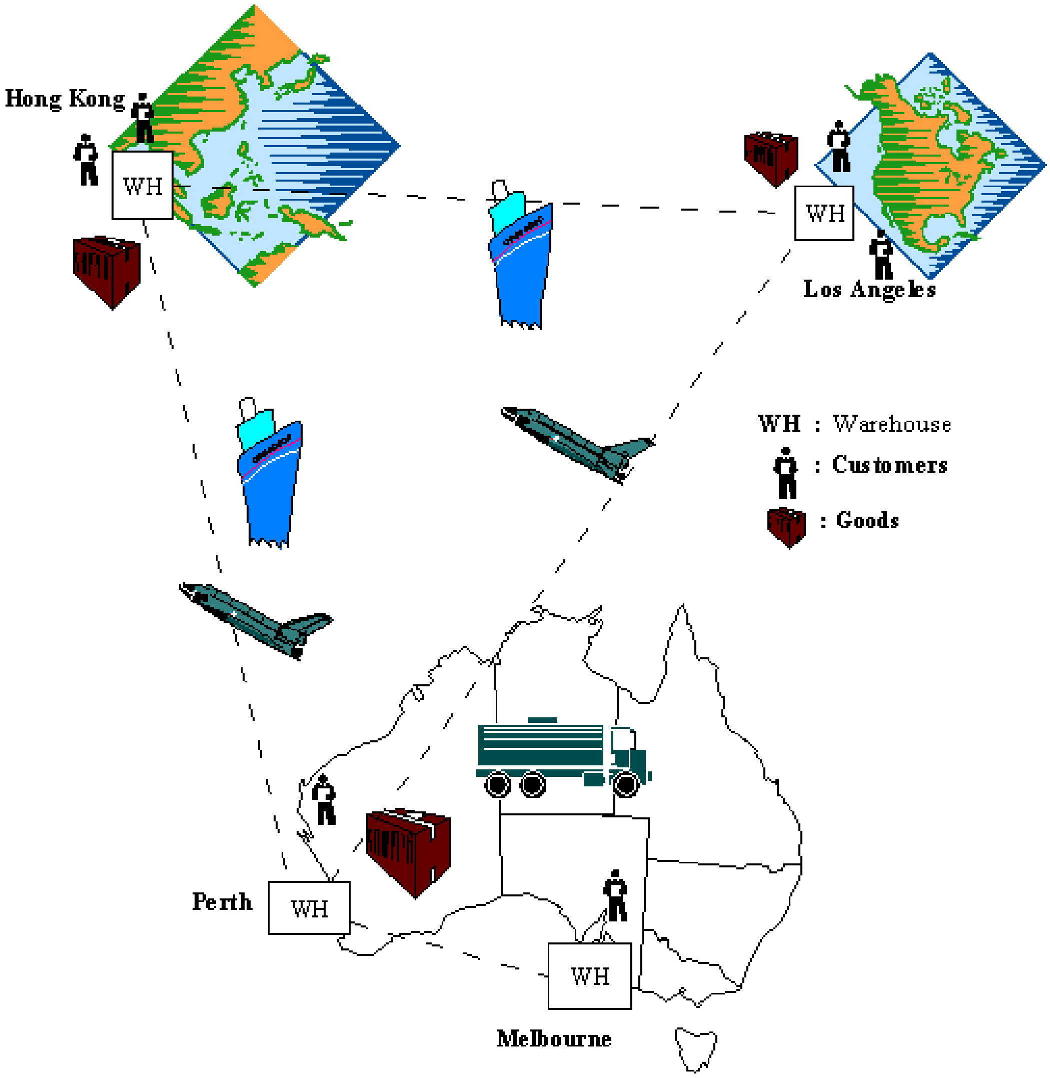


Figure 4-1: Global Collaborative Logistic Companies' Network

4.10 CONCLUSION

In this chapter, we describe in detail the collaborative workflow systems which play a central role in multi- and distributed organisations to work cooperatively to achieve business outcomes in intra-, inter- and heterogeneous environment settings. We have outlined business workflow processes, explained different types of workflow and given an example of how a collaborative workflow works.

Chapter 5 - Intra-Organisation Collaborative Workflow Modelling

5.1 INTRODUCTION

This chapter develops the modelling approach for intra-organisational collaborative workflow. We define business processes, relationship and dynamism and enable business strategies to be captured vigorously in the workflow so that changes can be handled simultaneously. We use extended activity diagrams to model the intra-organisational collaborative workflow. We demonstrate how the extended activity diagrams can model the intra-business processes efficiently while allowing business users to maintain control when dealing with changes.

5.2 ACTIVITY DIAGRAM

The activity diagram is one of the five diagrams in the UML for modelling the dynamic aspects of systems. An activity diagram is basically a flowchart that shows the flow of control from one activity to another activity. The activity is triggered by one or more events and may result in one or more events that may trigger other activities or processes. Events, which are message flows in UML, start from the start symbol and end with the finish marker and with activities in between connected by events. An activity diagram can be thought of as defining the actions in that process, which continues until everything that needs to be done, is done. Activity diagrams represent the decisions, iterations and parallel/random behaviour of the processing. Graphically, an activity diagram is a collection of vertices and arcs. A common use of the activity diagram is to model the dynamic aspects of a system. When we model the dynamic aspects of a system, we typically use activity diagram in two ways: to model a workflow where we focus on activities as viewed by the actors that collaborate with the system; and to model an operation. Here, we use activity diagram as charts that capture the flow of control, to model the details of computation.

Activity diagrams commonly contain the following elements: a filled-in circle, which indicates the start of overall activity (Figure 5-1a); an action, which represents an executable computation that cannot be decomposed further. It appears on an activity diagram as a lozenge shape (a symbol with horizontal top and bottom and convex sides) (Figure 5-1b); an activity, which represents a set of actions. It also appears as a lozenge shape, containing the name of the activity and perhaps some other information. (Figure 5-1c); a transition, which represents a change from one action state or activity state to another. A transition appears on an activity diagram as a solid line with a feathered arrow pointing to the new action state or activity state for the given object (Figure 5-1d).

A branch shows decision points where one path may become two or more new paths. It appears as a diamond on an activity diagram (Figure 5-1e). Synchronisation bars show how flows of control split (fork) and then join (Figure 5-1f). A filled-in circle contained within a larger open circle indicates the end of the overall activity (Figure 5-1g). UML also has a very useful technique in modelling a workflow called swimlane. It is used in an activity diagram too. A swimlane is a group. A group here represents the business organisations which are responsible for activities. Therefore, by having a swimlane, we partition the activity states on an activity diagram into groups. This technique gives us benefits in modelling and reading a workflow.

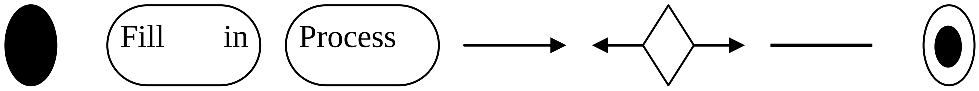


Figure 5-1(a-g): Notation system for Activity Diagram

In general, a workflow is considered as a collection of activities for the accomplishment of tasks. Each sequence of activities has to be executed in accordance with the business process of the organisation at hand (*Computers & Operations Research*, 2001). So, what should be the contents of a workflow model? The typical contents of traditional workflow models are:

- Organisational unit, which describes the organisation structure of a company (e.g. Department)
- Role, which describes virtual employees. Staff will be assigned to roles.
- Activity, also called task or function, which describes a piece of work within a business process.
- Data, which describes relevant data for the business process.
- Event, which describes an incident that might occur during the accomplishment of an activity.
- Resources, which describe a device, a machine or a tool, which will be required to accomplish a task. Process, which contains several activities in the order they have to be executed to attain a business goal of the company.

Jablonski and Bussler also discussed the main components of a workflow model. They discussed them as perspectives of the workflow model. There are five perspectives, which it is important that every workflow model should capture:

- Function perspective. It describes the functional units of a work process that will be executed.
- Operation perspective. It describes how a workflow operation is implemented.
- Behaviour perspective. It describes the control flow of a workflow.
- Information perspective. It describes the data flow of a workflow.
- Organisation perspective. It describes who has to execute a workflow or a workflow application.

A workflow model also can contain conditions or constraints because activities cannot be executed in an arbitrary way. Two types of conditions can be applied in a workflow model, which are pre-conditions and post-conditionm A pre-condition has to be satisfied in order to execute a workflow. A post-condition has to be satisfied in order to finish a workflow. These kinds of conditions also can be applied to a single task.

In Van der Aslst, W.M.P. and Jablonski, S. (2000), norm analysis is used to control the enactment of workflow. In the diagram, each control condition has a written label [N#] where # is the number for identification. The labels are then elaborated in the norm specification to indicate the condition, the agent and action to be taken. The norm here represents the business rules that are imposed on the particular process. In addition, the norms allow exceptions to be specified in them. Besides handling the business rules and exceptions, the norm provides a degree of flexibility that allows the modeller to introduce additional exceptions that may have been discovered in the later stages of analysis.

Moreover, in a workflow model, the following minimal information should be associated with each activity: who has control over the activity through the assignment of activities to qualified users or application functions.

Input /output of the activity, i.e. the data and control information required for task accomplishment pre- and post-conditions of the activity. Which other activities are required to complete the activity.

5.3 EXTENDED ACTIVITY DIAGRAMS

Since several new objects were introduced in the previous section, we need to propose some extensions to the activity diagram and new notation for the extended activity diagram.

An action can be viewed as a big object that contains other objects. It is still represented as a lozenge shape, but it has other rectangles above and below it. (Figure 5.2 shows the notation).

Note that, if the value of actor is none, it means that the action is an automatic one; otherwise it is a manual one.

To represent the interface of one action in a given worklet to another action in another worklet, we use the pentagon symbol (Figure 5.3)

To represent an exception handler object, we give worklet to another action in another use a hexagon symbol (Figure 5.4)

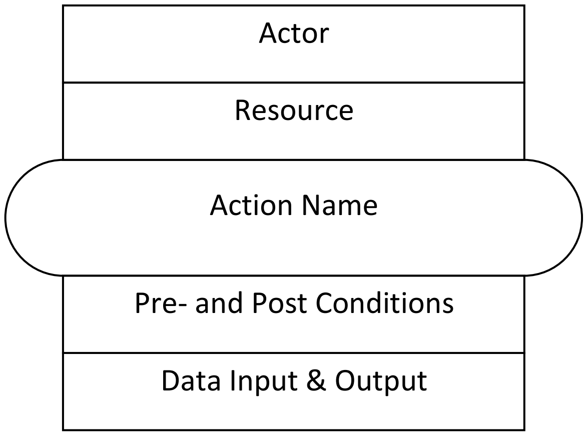


Figure 5-2: An Action Notation

Figure 5-3: An Interface Notation

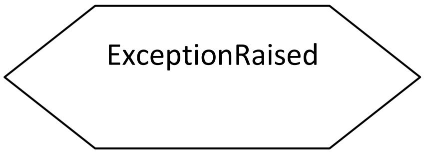


Figure 5-4: An Exception Handler Notation

For the remaining notations, we keep the notation the same as the UML activity diagram. We expect that these notations will help the modeller to have more flexibility in modelling a workflow. Having discussed other researchers' suggestions about the content of a workflow model, it is time to discuss our own perspective. By adopting the idea from the activity diagram of UML, we try to extend it so that it will provide us with the means of solving our initial problem.

In this approach, we suggest that a workflow model should contain these following objects:

- *Data*: represents the data that will be used or produced in an action (e.g. e-mail, order form)
- *Conditions*: represents the conditions associated with an action.
- Conditions can be divided into two kinds, namely *pre-conditions* and *post-conditions*. Pre-conditions are conditions that need to be satisfied so that an action can be enacted. Post-conditions are conditions that need to be satisfied on completion of an action.
- *Resource*: represents 'things' which will be required in order for an action to be performed, (e.g. machine, device).
- *Actor*: represents employees who will perform an action.
- *Action*: represents a piece of work; it can be a manual action or automatic action.
- *Worklet*: represents an activity/business process that is carried out by an organisational unit (e.g. Department)

5.3.1 **Worklet**

A worklet is a small workflow, which is carried out by an organisational unit. It contains one or more actions. One could think of a worklet as simply a sub-workflow; however, the main difference is that a worklet is a sub-workflow that is carried out by only one organisational unit. Each worklet has a unique *WorkletID.*

The idea of a worklet is to reduce the complexity of business process models. It makes less difficult the modeller's task of modelling and maintaining the models. Another objective of the worklet is to achieve independency of enactment of business processes across a company. Let us consider a company which produces a product where more than one department is involved in production. We believe that the workflow models will be very large. Moreover, if the production time is very long, then departments which have done their jobs, have to wait till the process finishes. This will be very time-consuming and inefficient.

An action in a worklet is able to interact with other actions in other worklets through its *interface*. An interface has two attributes: *Destination* and *Method*. Destination is WorkletID of an action with which the source action wants to communicate. A method represents the means that the actions use to communicate. It can be e-mail, mail, telephone, etc. Actions could have more than one interface. To support flexibility, the modeller can add new interfaces and assign the WorkletID and the method of the interfaces during the runtime (Braha D. Minai, A.A, Bar-Yan, 2006).

Each worklet must have at least one *Entry constraint*. The Entry constraint has to be satisfied in order to start a worklet. A worklet can be started either manually or automatically. To start a worklet manually, the user simply 'fools' the system. For example, when a customer places an order via telephone, there is no way for the system to automatically start processing the order. Human intervention is needed to start the worklet. The user should be able to enter the Entry constraint and run the worklet (e.g. by pressing 'start' button". On the other hand, to start the worklet automatically, human intervention is not needed. The system simply has to check the Entry Constraint frequently; if it is satisfied, then it will start the worklet automatically.

Since a worklet can be started in two ways, we have another attribute for the worklet, called *Start Method*. There are only two possible values for this attribute: manual and automatic.

Like other attributes of the worklet, the value of the Entry Constraint and the Start Method can be changed at runtime and the number of Entry Constraints can be added or reduced.

Figure 5-5 An Interface Notation

5.3.2 **Action**

An action is a single task which is performed by an actor or actors. Actions can be categorized into two types in terms how they are done: *manual-action* or *automatic-action.* A Manual-action is an action that is manually performed by actors (e.g.

filling an order). Meanwhile, an automatic-action is an action that is automatically performed by the workflow management system (e.g. sending an e-mail).

Ideally, an action cannot be done in an arbitrary way. There should be conditions that need to be satisfied first to enact the action. These conditions are called pre-conditions and could be the business rules of the business process. Post-conditions are conditions that need to be satisfied so that a task can be said to be ‘complete’ or ‘done’. An action also can have input and output, in the form of data, documents or other objects (e.g. order form).

As for a worklet, human intervention is needed for manual-action. There is no way for the system to know whether or not a manual-action has been performed. Users must let the system know if they have finished doing their jobs (e.g. by pressing ‘done’ button).

An action can be viewed as a big object that contains other objects. It is represented as a rectangle shape, but it has inward and outbound arrows above and below it. Figure 5.1a below shows the notation. Note that, if the value of actor is none, it means that the action is an automatic one; otherwise, it is a manual one.

To represent the interface of one action in a given worklet to another action in another worklet, we use the pentagon symbol (Figure 5.1b).

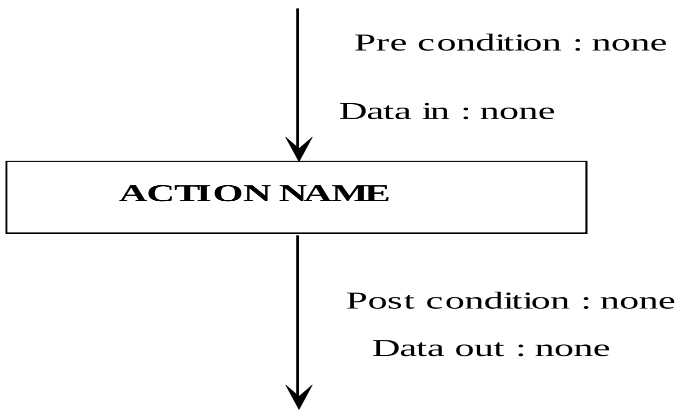


Figure 5-6: An Action Notation

5.3.3 **Exception Handler**

To support flexibility, we propose another object and it is part of the action object. This object is for handling an exception that might occur in the process instance level. The object is called *ExceptionHandler*. It has two attributes, the first being a Boolean attribute called *ExceptionRaised*. The default value of this attribute is false. However, one could change this value during runtime when an exception is raised. The second attribute is an *ExceptionRule*. This ExceptionRule contains the rule which specifies what action should be taken when an exception occurs. The action could be anything. It could be redoing the current action; executing a single action or executing another worklet. If the action is executing another worklet, then the worklet itself can be modelled in an ad-hoc way. This technique allows the modeller to change and extend the original workflow in order to handle exceptions.

However, one has to remember that this change applies only to a single process instance or case. This change will not affect the original process/worklet definition; therefore the other process instance still adheres to the old definition. This technique can be used if the exception will not occur in the future. However, if the exception occurs frequently, we suggest that the changes should be applied directly to the process definition so that remodelling the workflow at runtime is avoided.

In the next section, we use this extended activity diagram to model a real-world business process of a logistics company in Australia.

5.3.4 **Reconfigurable Workflow Object**

We believe that a high-level flexible workflow modelling language is not enough to overcome the problems of complex collaborative workflow management systems. We need to be able to add, modify or remove the attributes of workflow objects in a workflow model. The operations associated with each workflow objects should be able to be change to meet the dynamic changing business environment.

Most object-oriented systems are developed in a rigid manner. They are developed based on a static model, modelled by system analysts and translated to code by programmers.

To be able to add, modify or remove attributes, we model an object as a ‘container’ which hold its attributes and values. (e.g. a 2 dimensional array). We also need some methods to add, modify and delete attributes. These methods are fixed codes. Figure 5.7 shows a model of the object.

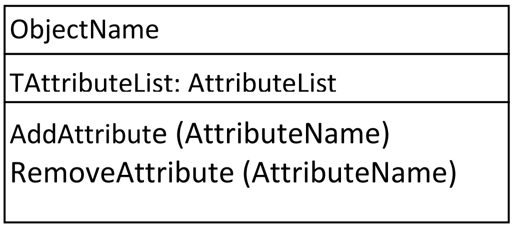


Figure 5-7: A Flexible Object Model

5.3.5 **Generic Worklet**

A generic worklet is a worklet that can be used as a template that can then be used to model another worklet of another business process. For example, a worklet for handling a customer order can be used to model a worklet for handling an order for a customer. (This could happen because, for example, a customer does not have access to the Internet, so she orders the service via telephone. Then, the CS-Dept will fill in the order on behalf of the customer.) Figure 5.8 shows the generic worklet, and Figure 5.9 shows the worklet for handling an order on behalf of a customer. As we can see, the second worklet is almost the same as the first worklet; the difference is that the second worklet has one additional action (shaded grey).

The goal of the generic worklet is to reduce time for modelling a worklet. Since we already have a template, we simple use that so we do not have to spend much time to model a new worklet. We have to modify it only a little for our new worklet.

Support reuse in workflow modelling. During our survey of previous work, based on our knowledge, we did not find any papers that talk about reuse in workflow modelling. It seems that reusability is not a focus of current research in workflow modelling. However, we believe that reusability is an important aspect that needs to be considered in order to support flexible workflow modelling.

Correctness. By reusing a tested worklet, we ensure that, at least, a new worklet is built on top of a correct worklet.

One problem that needs to be discussed regarding reusability is the need for a technique to store and retrieve generic worklets. One solution is to have a global repository so that each user across the company can access, store and use the generic worklets.

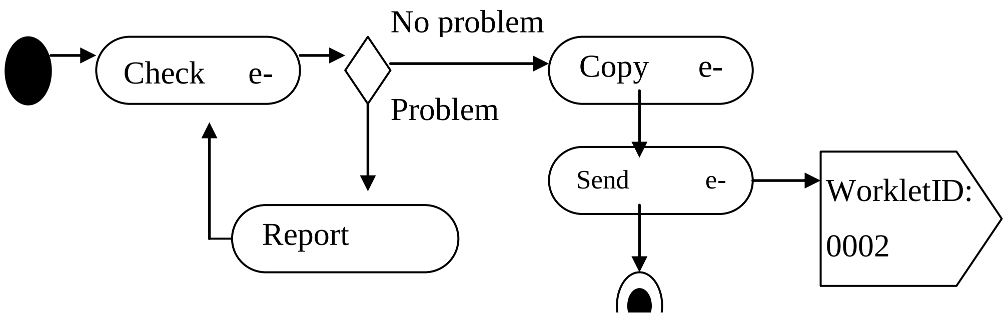


Figure 5-8: A Generic Worklet for Handling Order

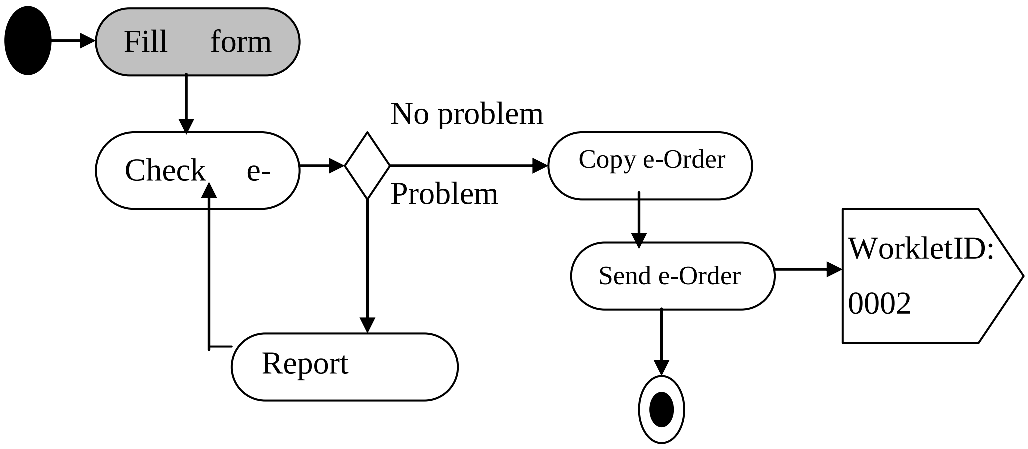


Figure 5-9: A Generic Worklet for Handling Order on Behalf Customer

5.4 APPROACH TO MODELLING

This methodology adopts the activity diagram of UML. We extend this diagram by introducing new concepts and notations and show that it can be used to model a flexible workflow.

We start by developing a conceptual framework of workflow management through managerial, administrative and operational workflow and further refine the workflow structure of an organisation and to formalize the workflow model concepts and definitions, and define workflow components' properties and their relationship with other workflow components and worklet. We then develop modelling diagrams that can represent the dynamisms and flexibility of the workflow components that can adapt to changes quickly and facilitate use of extended activity diagrams.

This is followed by the development of a prototype model to facilitate modelling processes and demonstrate the change.

We then evaluate the method by applying it to the logistics' industry and the industry partners associated with this thesis project.

5.5 MODELLING INTRA-ORGANISATIONAL COLLABORATIVE WORKFLOW

In this section, we apply our proposed methodology of extended activity diagrams to a real-world business process. This business process example is taken from a warehousing and logistics company, in the real world. Logistics Management, broadly defined, is concerned with the strategy and management of the movement and storage of materials and products from suppliers, through the firm's distribution systems to retail outlets and customer. The scope of logistics management for the physical movement of goods starts with the sources of supply and ends at the point of consumption (Dami, S., Estubiler, J., Amiour, M., 1996). TLogistic management is part of supply Cchain management.

In today's business environment, good logistics management often determines the success of a business. Retailers are well aware of how excess inventory, frequent stock-outs, poor item turnover, and excessive markdowns can cut into profits. Logistics management attempts to achieve a balance between holding minimum stock while providing the best services possible to the customer.

5.5.1 **Case Study Example: A Logistic-Warehouse Operator**

The company modelled is one of the largest warehouse and logistics companies in the Asia Pacific region. Its main service is to provide space for customers who want to store their goods in a warehouse and shift their goods from an origin location to destination location. We will use the acronym **LC** to indicate the **Logistics**

Company. The company LC provides detailed logistics services for its customer to move their goods from one place to another place. In this project, we concentrate only on the logistics operation.

LC has many types of logistics orders and each order has its own flow of work. Some of these orders are:

Import: means that customer wants LC to pick up goods from one place and bring it to LC's warehouse.

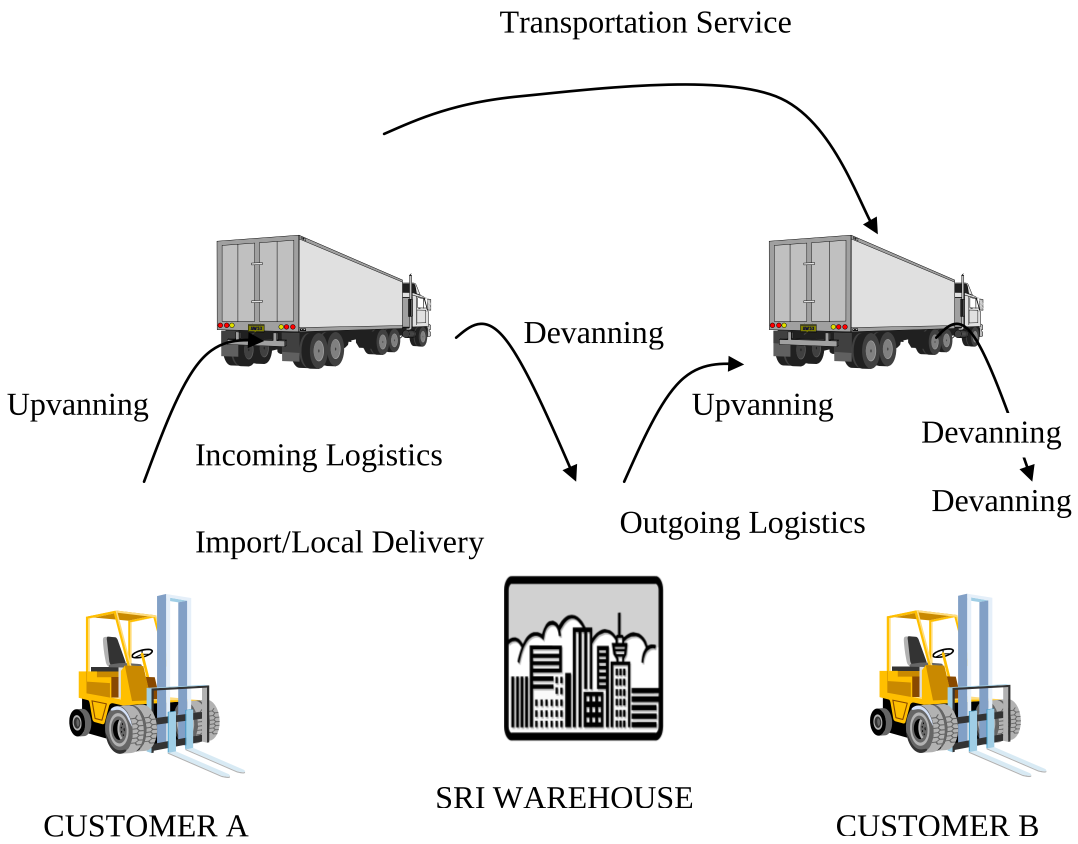


Figure 5-10: Basic Warehouse Services

These goods are coming from outside Australia and the goods have to be declared/checked in the Customs Office before entering Australia. So they are usually picked up from either a seaport or an airport.

Export: means that the customer wants LC to deliver the customer's goods from LC's warehouse to either seaports or airports in Australia. These goods also need to be declared/checked before leaving Australia.

Local Delivery: means that the customer wants LC to transport customer's goods from one place to another place within Australia.

All these orders involve other types of work such as *Devanning* and *Upvanning*. Devanning is the process whereby goods are moved from trucks and put in the warehouse. However, the process is not this simple. Some goods-checking procedures have to be undertaken to ensure that the goods are stored in the correct warehouse (e.g. frozen fish have to be put in a cold-warehouse) or to find out if there are any discrepancies between the number of goods in the order and the actual number of goods that are delivered to the warehouse. Upvanning is simply the opposite of Devanning. Figure 5.10 shows the basic services which LC provides to its customers.

5.5.2 **Intra-Organisational Collaborative Workflow**

LC consists of five departments: warehouse logistics accounts, customer service and transport.

Although each department has its own responsibilities, the departments are connected to each other. The warehouse department now already has its own system, as does the accounts department.

Currently, the workflow of the logistics management is not integrated into the existing Warehouse Management System (WMS) or the accounting system. The co-ordination and delivery of goods are initiated by clients using traditional means of transmitting requests either by telephone or fax. The system uses spreadsheets to manage and update the delivery and transportation charges. The information is fed manually to the accounting department for necessary updating of the account receivables (David Neumann, 2004).

All these works are done manually, time consuming and prone to error. The complexity of works are become bigger and bigger when the customers' order are increasing. It is hard to keep track of the progress of the orders. The site manager has to go down to the warehouse floor to check them. It is also difficult to schedule the trucks, manpower, etc. Due to all these problems, recently LC likes to change the way they are doing business now. LC likes to change its internal work (flow of work among the departments) and its external work (flow of works with its customers). LC would like to use computers to automatically handle all the movement of papers or documents from one department to another department. LC also wants its customers to be able to book warehouse and logistics services, place orders, view the status of orders, etc. on the Internet. This is more like an e-commerce way of doing business. Figure 5.11 shows a typical e-commerce application network (Chang et al., 2001).

5.5.3 **Business Objectives Through Collaborative Workflow**

To help LC, we need to build a new LC business process model by using our extended activity diagram. Our goal is to manage the complexity of the business process model and also to build a flexible model so that it can be changed easily as the business processes are changing. Furthermore, the model can be used as guide for developing LC's logistic management system. In this section, we demonstrate the Local Delivery order type.

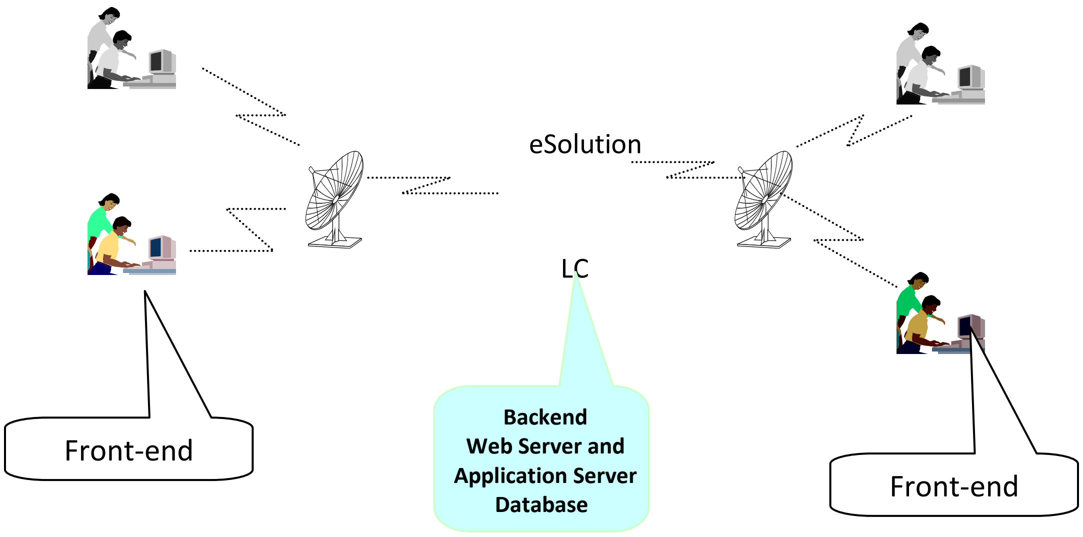


Figure 5-11: Typical e-Commerce Application Network

As described previously, Local Delivery is an order from a customer to move the goods from one place to another place within Australia. The high-level workflow representation for Local Delivery is shown in Figure 5.10

From this high-level representation, we develop a more detailed model using our methodology. We decided to have five worklets, CS-Dept worklet, LOG-Dept worklet, WH-Dept worklet, TRN-Dept worklet and ACC-Dept worklet. All the worklets communicate through e-mails. We assume that customers place orders on LC's web site (client side), and once they finish providing all information, it will be sent to LC as e-mail, called e-Order. LC staff also have their own web site (server-side) to process all the e-Orders.

5.6 USING THE EXTENDED ACTIVITY DIAGRAMS TO MODEL A LOGISTICS ENTERPRISE

5.6.1 Customer Services Department Worklet

The main task of the Customer Services (CS) -Dept in LC is to take care of all enquiries from LC's customer. The CS-Dept also can place orders on behalf of customers. This is because the customers may not have a connection to the Internet so they cannot fill in the order from the LC client web site.

Another duty of the CS-Dept is to check and validate all the e-Orders. If there are problems with the e-Order, then the CS-Dept will report the problems to the customer and the order will be suspended until all the problems are fixed.

After checking and validating the e-Orders, the CS-Dept will make a copy of the e-Order and forward it to either the Logistic department or Warehouse department through e-mail. The high level CS department workflow is shown in Figure 5.12 below.

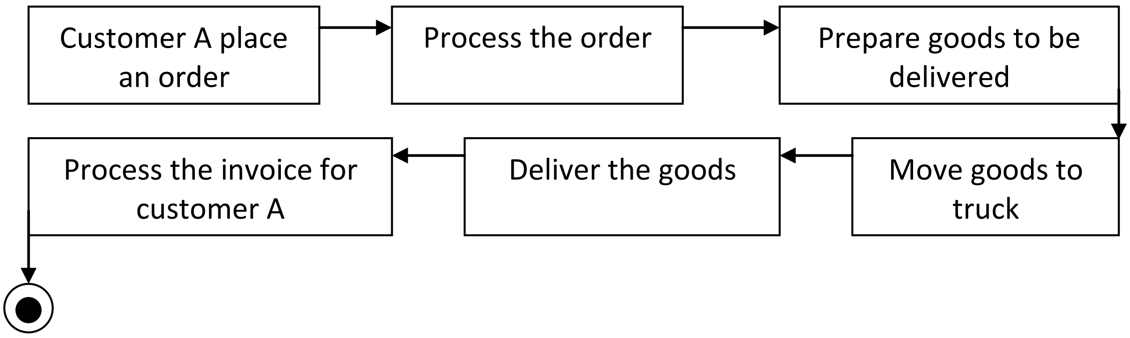


Figure 5-12: High-level Workflow Representation of Local Delivery

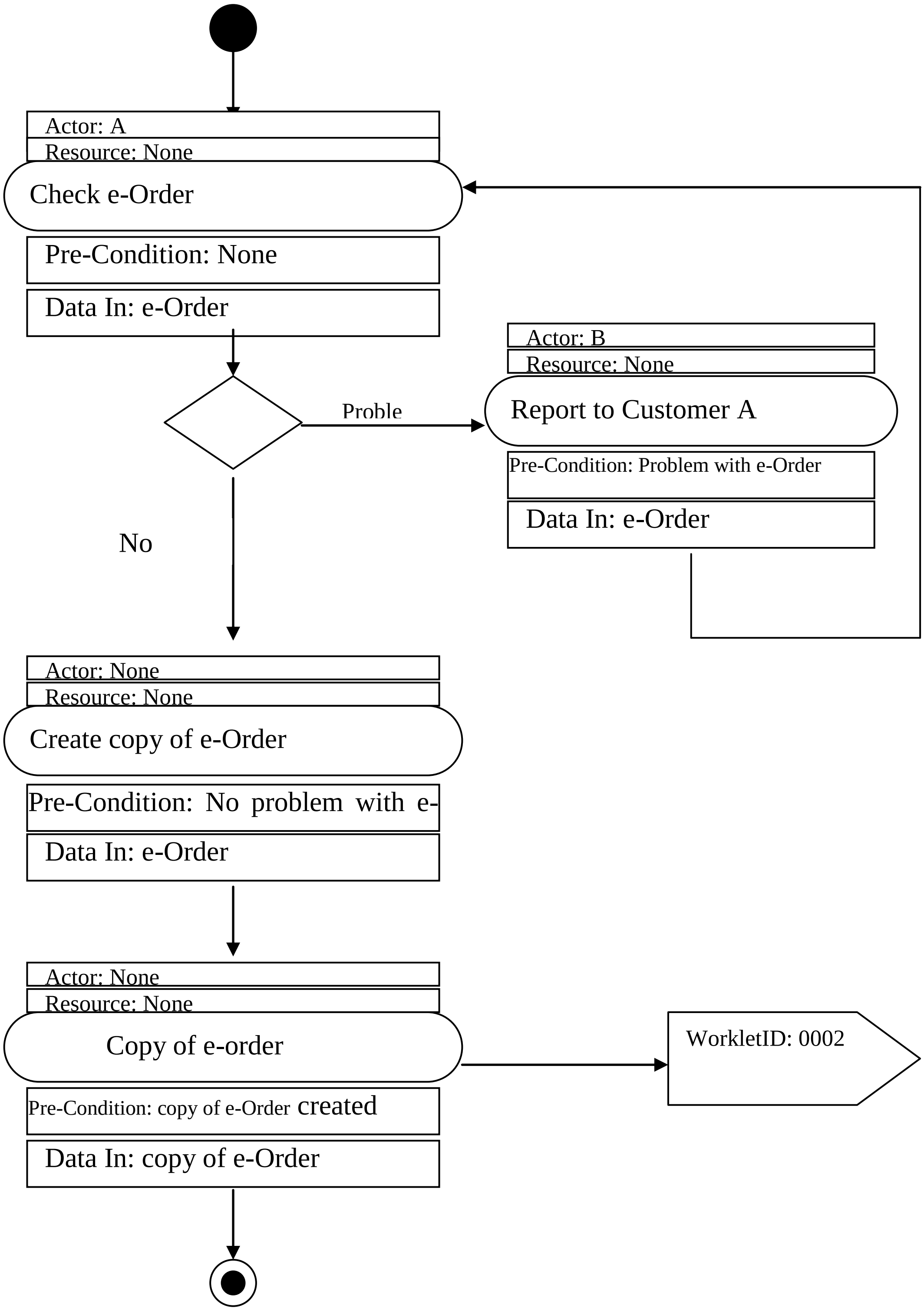


Figure 5-13: CS-Dept Worklet , WorkletID: 0001

Entry condition: e-Order is received

These two latter tasks are performed automatically by the system. After sending the copy of e-Order, the CS-Dept worklet then reaches the finish state. The entry condition of the CS-Dept worklet is an e-Order received from a customer by the system. For convenience, the WorkletID for CS-Dept is 0001. Figure 5.13 shows the CD-Dept Worklet.

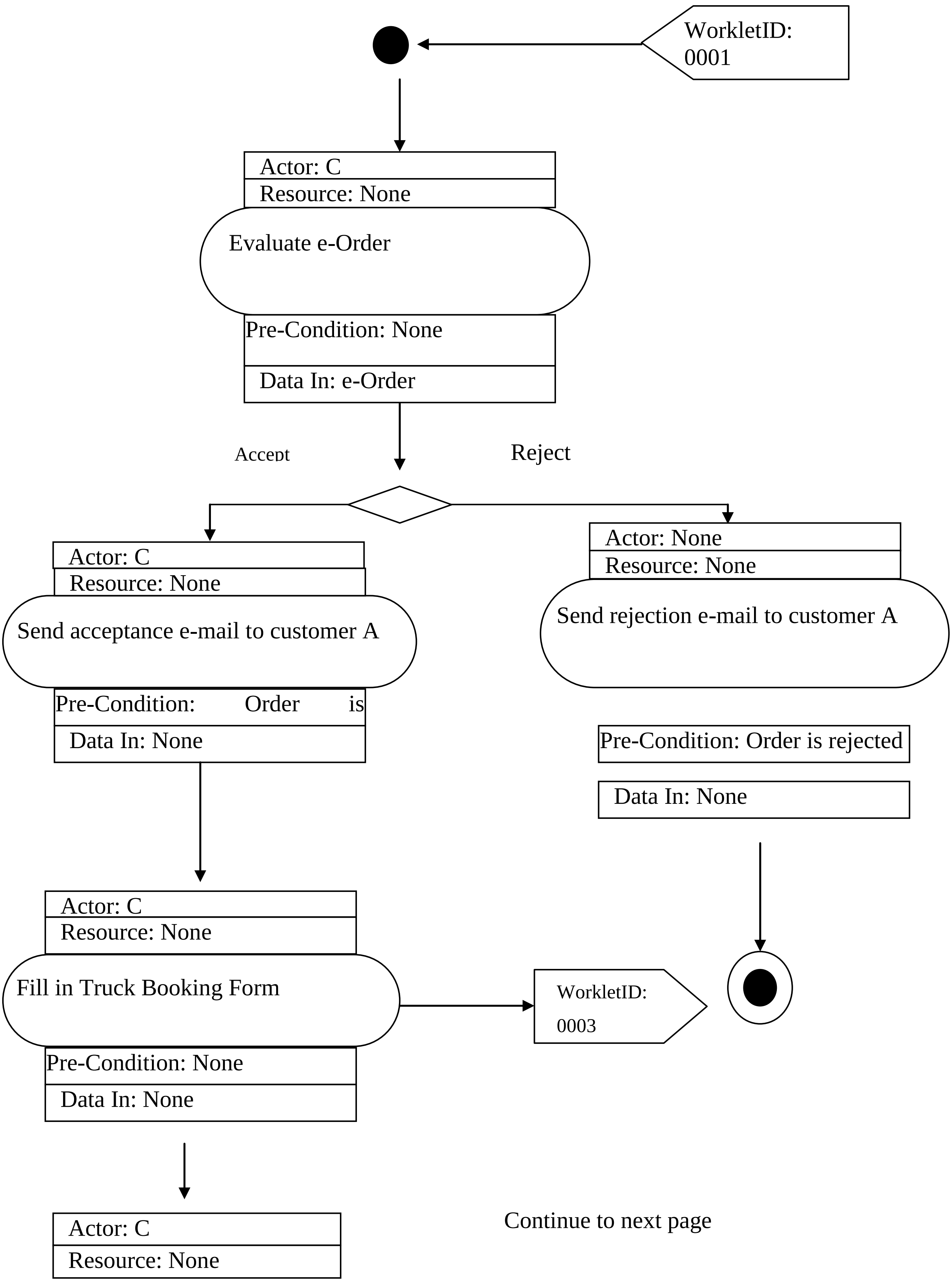
5.6.2 **Logistics Department Worklet**

The Logistics department (LOG) has many duties here. The first one is to decide if LC wants to accept or reject the order. An order can be rejected for several reasons. For example, Customer A wants to export 20 tons of chicken wings to Customer B. However, when the Logistics department checks the warehouse database, Customer A has only 10 tons of chicken wings. Therefore, the e-Order has to be rejected. The Logistic department then sends a rejection letter to the customer along with the reason and the worklet reaches the finish state. If the customer is on the Internet, this notification would be done by e-mail.

If the e-Order is accepted, the Logistics department will send an acceptance letter and the next task is to book trucks for delivery. The Logistics department sends all the information about the delivery, date of delivery, type of truck, etc. From here, we are waiting for confirmation from the Transportation department. Once the confirmation is received, the Logistics department then reports to the customer that the order is confirmed.

Next, the Logistics department will notify the Warehouse department to prepare the manpower and the goods for the upvanning process. After that, it will fill in a charges form (from staff web site) and send it to the Accounts department. The worklet then reaches the finish state. We assign the WorkletID for the Logistic Department to 0002. The entry constraint for it is an e-Order received from the Customer Service Department. Figure 5.14 shows the diagrammatic presentation of the overall process for Warehouse upvanning logistics.

WorkletID: 0002.Entry condition: e-Order is received from the CS-Dept.



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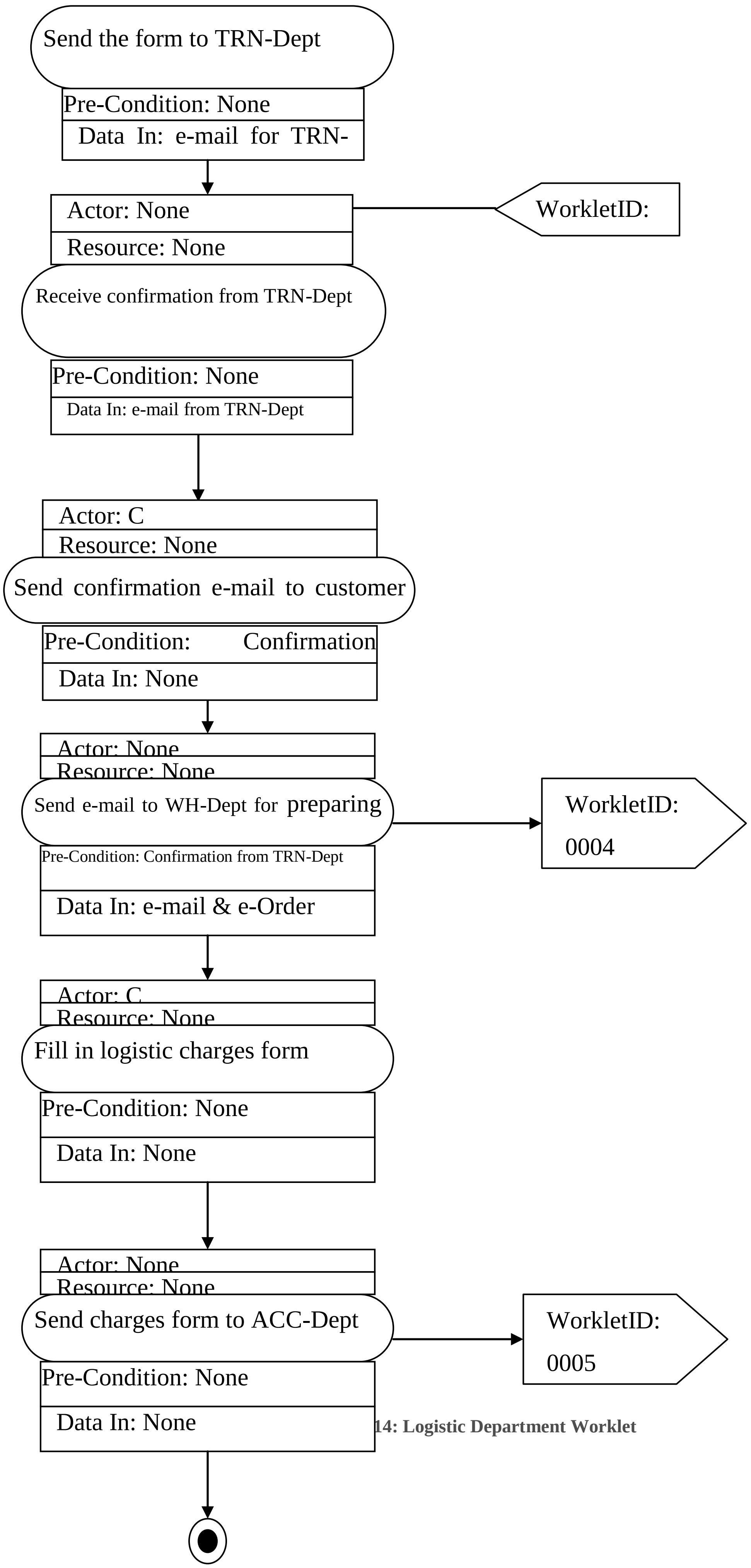


14: Logistic Department Worklet

5.6.3 **Transport Department Worklet**

The main duty of the Transportation department (TRN) is to schedule and assign LC's trucks to a particular e-Order. The first task is to query its database and find out the availability of the required truck from an e-Order. If the truck is not available, then it has to contact another transporter company and book a truck from it.

After it finds the required truck, it will send the confirmation to the Logistics department, indicating that the required truck is available. The next task is to ask the truck to go to the warehouse to pick up the goods. We assign the WorkletID for the Transport department to 0003. The entry constraint for it is that a truck-booking request, in the form of e-mail from the Logistics department must be received.

This task is performed when the goods in the warehouse are ready (pre-condition of the task). This is because we do not want the truck to be waiting too long in the warehouse, especially when the truck comes from another transport company, which will make the charges for the truck higher.

Once the goods are in the truck, they are delivered to Customer B and the worklet reaches the finish state. Figure 5.15 shows the diagram of overall process.

WorkletID: 0003.

Entry condition: Truck booking e-mail is received from LOG-Dept.

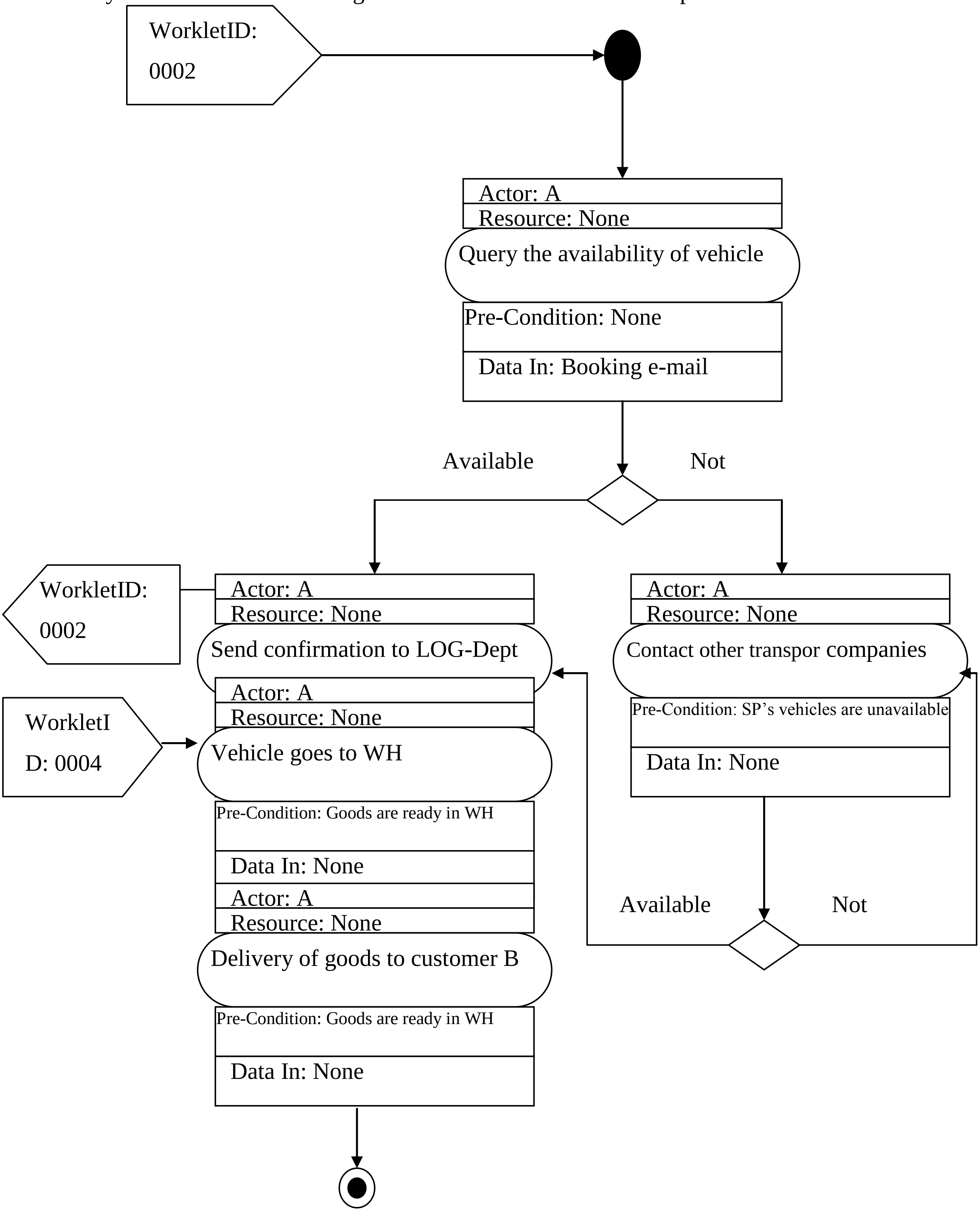


Figure 5-15: Warehouse Department Worklet

5.6.4 **Warehouse Department Worklet**

The main duty of the Warehouse department (WH) is to prepare the manpower and the goods. Once the goods are ready, it will notify the Transport department so the truck can come to the warehouse. Another task is to move the goods to the truck. Once this has been done, the worklet then reaches the finish state. We assign the WorkletID for Warehouse department to 0004. The entry constraint for it is a request from Logistic department to prepare manpower and goods for local delivery service. Figure 5.16 shows the diagram of the overall process.

WorkletID: 0004.

Entry condition: E-mail request from LOG-Dept is received. This request is for preparing the goods to be delivered.

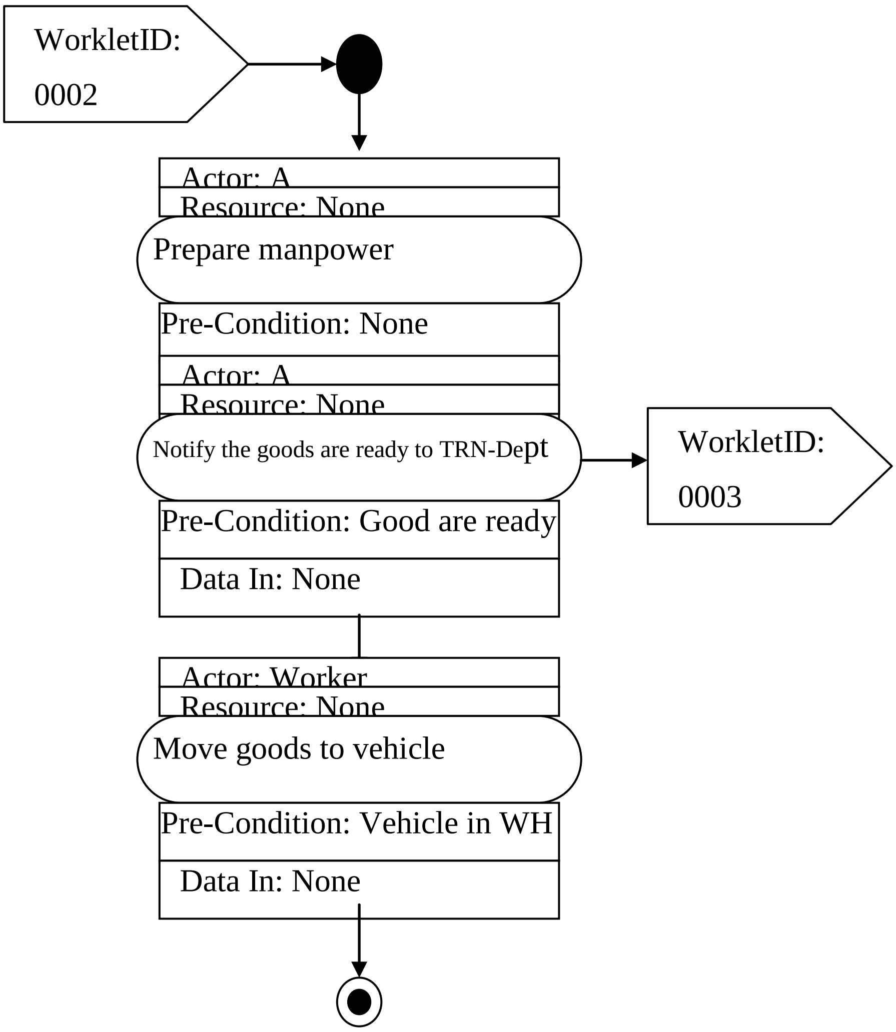


Figure 5-16: Warehouse Department Worklet

5.6.5 **Accounts Department Worklet**

The main duty of the Accounts department (ACC) is to process the charges form that it receives from the Logistics department (in the form of an e-mail). Once the Accounts department has finished processing the form, it generates an invoice and then sends it to the customer and the worklet reaches the finish state. We assign 0005 as the WorkletID for the Accounts department. . The entry constraint is that a charges form from the Logistics Department must be received.

Figure 5.17 shows the diagram of the overall process.

WorkletID: 0005 Entry Condition: Charges form from LOG-Dept is received.

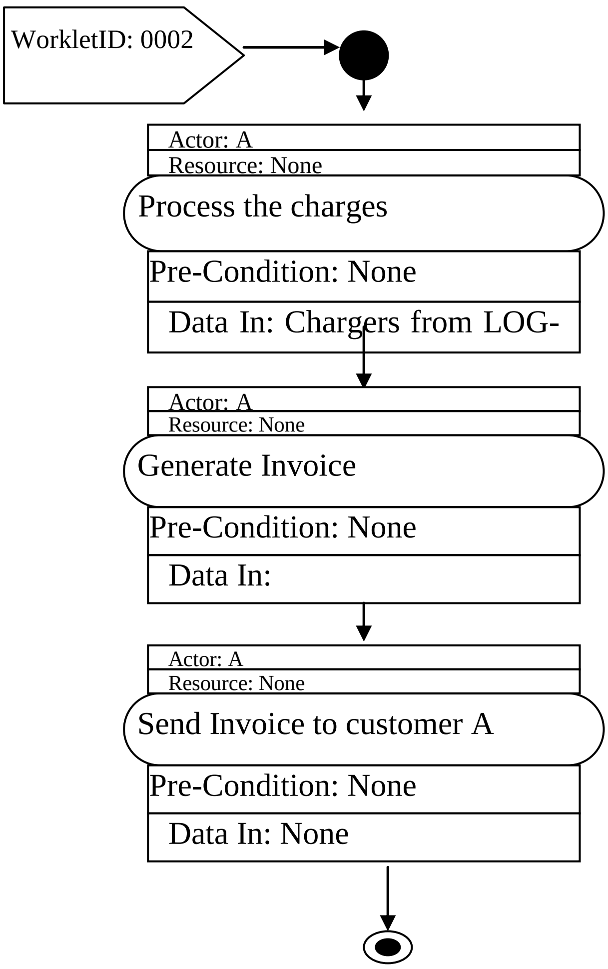


Figure 5-17: Account Department Worklet

5.6.6 **Time Sequence in Collaborative Activities**

Activities and artefacts do not quite constitute a process. We need a way to describe meaningful sequences of activities that produce some valuable result, and to show interactions between processes. Changes in collaborative workflow have to be incorporated into the integrated enterprise system. In this section, we focus on:

1. Adaptation of changes into an existing workflow;

2. Synchronisation of new workflow to existing workflow; and

3. Management of data scattered over multiple origin systems/legacy systems.

As an example, a company will have consolidated its data into one logical view with a unified architecture, thereby enabling data-source independence. Because application data continues to exist and change in the original systems, the new software layer must be able to retrieve original data on the fly and also propagate changes back to the original systems (Chang, E., Dillon, T.S. and Hussain, F., 2005). This provides support for transactions/interaction across multiple back-end systems.

These factors will help to create a uniform data processing environment for the whole enterprise, which would lead to changes and improvements in customer services, control of receivables and increase efficiency in communication, sales, marketing as well as minimization of warehouse stocks, streamlining inventory and logistics flows.

Providing control to consortium management to monitor the collaborative enterprise’s condition, its stock, order and its general financial condition on a routine basis, is indispensable to the management processes and enhances decision-making and changes which need to be made for both the short- and long-term in order for the consortium to compete successfully in the global market.

5.7 EVALUATION

In this section, we have shown how to model a business process by using our extended activity diagram. The main concepts of our diagram are worklet, interface and exception handler. Worklet and interface have addressed the problem of the complexity of a model. They also have addressed the problem of supporting inter-organisational companies. Meanwhile, the exception handler has addressed the problem of coping with exceptions, which could occur in a business process.

We have applied the proposed methodology to a real-world business process - a warehouse company in the real world. Warehouse management, in its broadest definition, is concerned with the strategy and management of the movement and storage of materials and products from suppliers, through the firm's distribution systems to retail outlets and customer. The scope of logistics warehouse management for the physical movement of goods starts with the sources of supply and ends at the point of consumption (Dami, S., Estubiler, J., Amiour, M., 1996). Logistics management is part of supply chain management.

In today's business environment, good logistics management often determines the success of a business. Retailers are well aware of how excess inventory, frequent stock-outs, poor item turnover, and excessive markdowns can cut into profits. Logistics management attempts to achieve a balance between holding minimum stock while providing the best services possible to the customer.

5.8 CONCLUSION

In this chapter, we presented a method of large complex systems using the concept of a worklet and workflow. We then introduced extensions to the UML-based activity diagrams to allow modelling of these flexible adaptive workflows. This is illustrated using the real-life example of a logistics system.

Chapter 6 - MAO Model Based Intra-Organisation Workflow Management

6.1 INTRODUCTION

In this chapter, we propose a MAO model to manage the collaborative workflow within an organisation. As described in the last chapter, this is called an intra-organisation collaborative workflow. As part of our workflow management proposal, we also propose workflow mining to help manage the changes to the workflow.

6.2 THE MAO MODEL

The MAO model framework is developed from the general business organisational management principles, and focuses especially on workflow management. The MAO model comprises the following workflow management components, namely:

- Managerial workflow
- Administrative workflow
- Operational workflow

These workflow management components need to communicate, cooperate and collaborate in order to maximize the productivity, efficiency and performance.

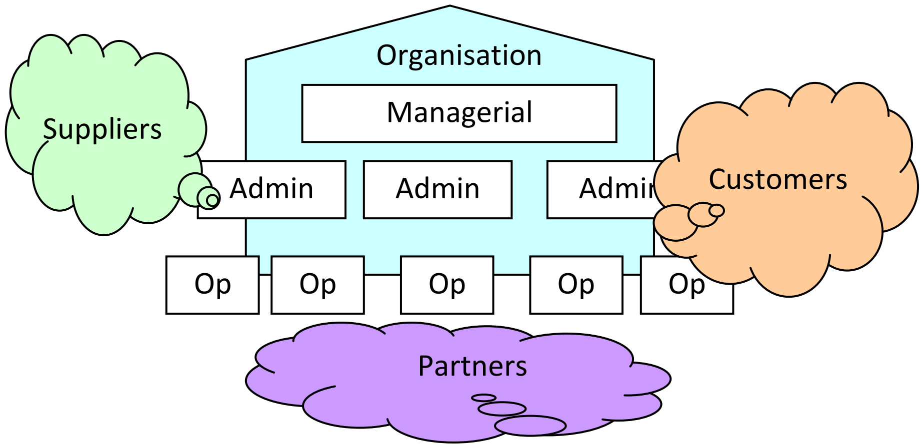


Figure 6-1: Mao Model for Intra-Organisational Workflow Management

The MAO model follows traditional hierarchical management principles for generic business organisation management. As businesses forge into the 21 century, we see this hierarchy management principle moved forward with a more flexible and self-organised component-based managerial structure. In the next few sections, we define each of the workflow management components within the MAO model and how they apply to intra-, inter- and heterogeneous organisation workflow environments.

6.2.1 **The Managerial Model**

Managerial workflow governs the entire administrative workflow and operational workflow. It is executed through strategic decision-making, and this strategic execution is driven by business operation planning, change management and outcome evaluation. Over the execution of the managerial workflow component, it collaborates with the administrative and operational workflow components. The managerial workflow component is the primary cause of the dynamic workflow changes in an organisation. In our opinion, the managerial workflow is usually unstructured, dynamic and the process changes over time and is driven by market pressure, economic competition and business value; therefore, managerial workflow is dynamic, flexible sometimes ad-hoc, thereby making the administrative and operational workflow component flexible, which in turn produces managerial workflow changes. The administrative workflow and operational workflow component can be automatically or semi-automatically changed. Therefore, in this research we model the flexibility and dynamism of managerial workflow and make the administrative workflow component and operational workflow component flexible.

6.2.2 **The Administrative Model**

Administrative workflow is decomposed into four sub-components: Administrative control workflow, Accounts management workflow, Human resources management workflow, Customer relations workflow.

Administrative control workflow is involved in making decisions and the prioritizing and scheduling of tasks. The administrative task workflow is measured by its efficiency while Managerial workflow carries out business decisions, which in turn control the entire business administration and is measured by the final results.

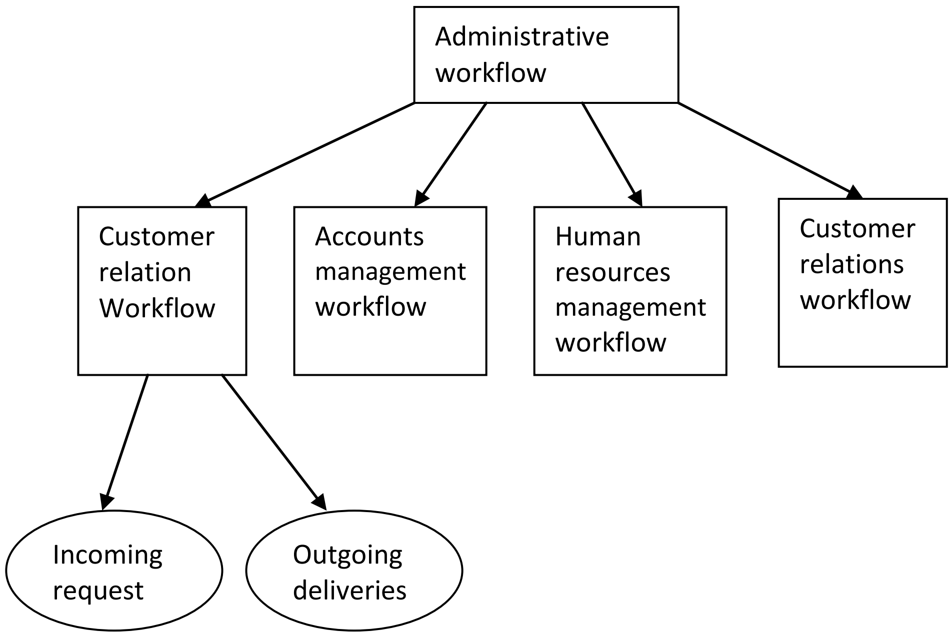


Figure 6-2: Administration Workflow Component in Intra-organisational Workflow Management

The collaboration of these workflow components is depicted by the following collaboration of diagram utilising UML notations. Collaboration diagram 6.1 shows a major workflow consisting of: managerial workflow, administration workflow and operational workflow

The arrow shows one way of the flow control. Customer service workflow is decomposed into incoming requests and outgoing deliveries. Customer service workflow relates to order requests and order fulfilments. Incoming order workflow takes the customer input and outgoing service workflow delivers the service to its customers.

6.2.3 **The Operational Model**

Operational workflow relates to the core business operations and is usually measured by its performance and by the volume of its output. Operational workflows are the main sources of value generation for the organisation. It can further be decomposed into Ooperational control workflow and production workflow.

Operational control workflow initiates the day-to-day operations and production workflow consists of the tasks and activities required to produce goods and services and it is measured by productivity; it can be decomposed further into input workflow, action or task workflow and output workflow. It is measured by the production output.

We note that administration workflow and operational workflow are relatively structured and stable in an organisation. Their changes occur over time but not randomly and frequently. The efficiency of administrative workflow management and performance of the operational workflow management creates value for the organisation. It is important that these workflows are improved and updated over time to allow the company to stay at a competitive advantage. So we find that the course of the above two workflows is due to the changes in the managerial workflow.

6.3 HIERARCHICAL RELATIONSHIPS BETWEEN WORKFLOW COMPONENTS

Following the previous section, we define the relationships in an organisation as follows:

- Operational workflow
- Administrative workflow
- Managerial workflow

The conceptual representation of the relationships is shown is Figure 6.3.

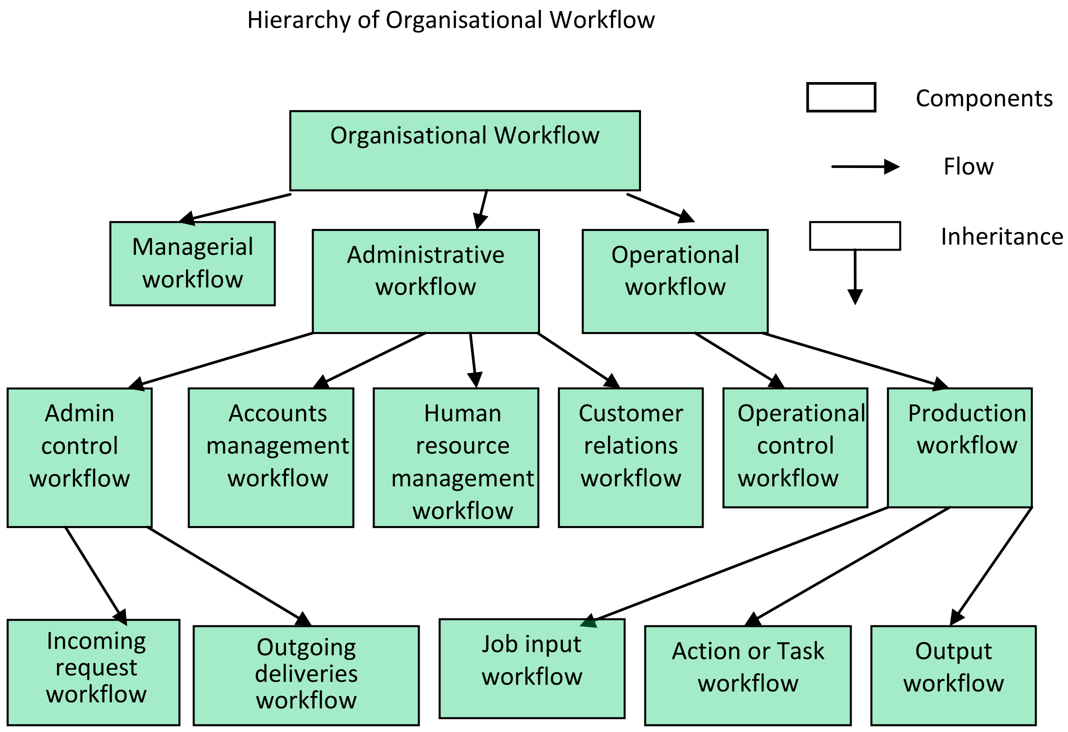


Figure 6-3: MAO Organisation Hierarchy Workflow Model

Operational Workflow is the main source of value generation for the organisation. It can further be divided into the following: 'Operational control workflow' and 'Production workflow'. Operational control workflow initiates the day-to-day operations and production workflow contains the tasks and activities to produce goods and services and is measured by productivity.

Administrative Workflow is divided into four subcomponents; 'administrative control workflow', 'accounts management workflow', 'human resources management workflow' and 'customer relations workflow'. Administrative control workflows are involved in making decisions and prioritizing and scheduling tasks. The administrative task workflow is measured by its efficiency.

Managerial Workflow carries out business decisions, which in turn control the entire business administration and is measured by the financial and final results. The hierarchy of the aggregation of the workflow components is shown below.

6.4 COLLABORATION BETWEEN THE WORKFLOW COMPONENTS

We illustrate the collaboration of these workflow components in Figure 6.4. The collaboration diagram in Figure 6.1 shows three major workflows: managerial workflow, administration workflow and operational workflow. The arrows show one way of the flow control. Customer service workflow is sub-divided into incoming request workflow and outgoing deliveries workflow. Customer service workflow relates to events such as order request and order fulfilment. Incoming order workflow takes the customers' input and outgoing service workflow delivers the goods and services to the customers.

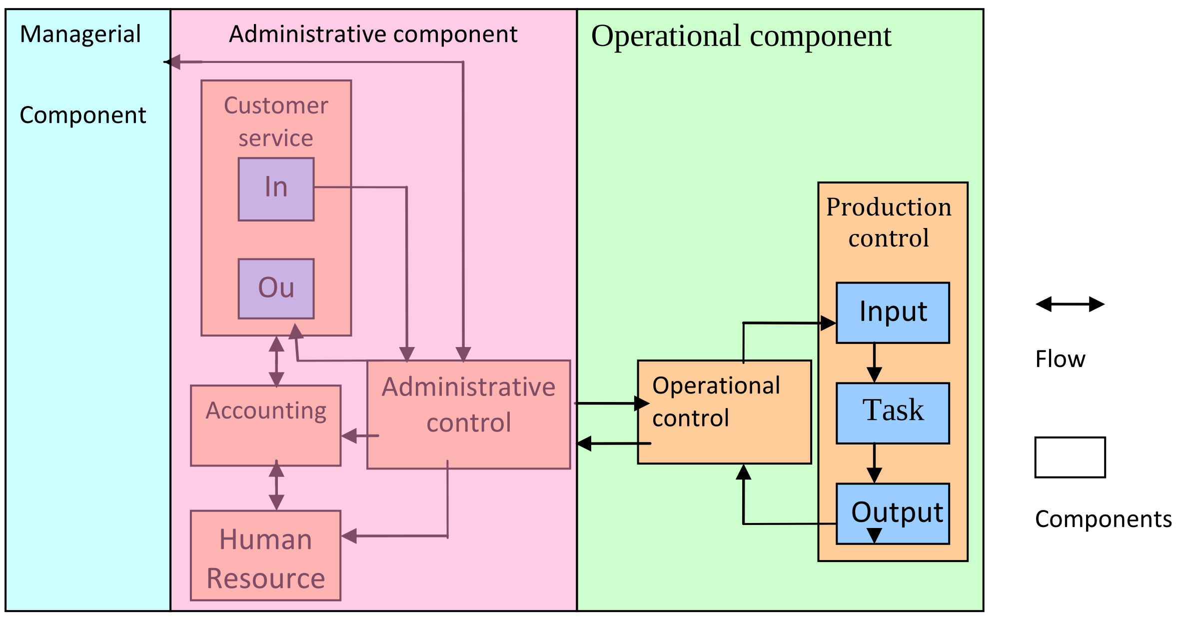


Figure 6-4: MAO Model in Collaboration Diagram Representation

Note that ***administration*** workflow and ***operational*** workflow are relatively structured and stable in an organisation. Their changes are not random or frequent. The efficiency of administrative workflow management and performance of the operational workflow management create value for the organisation. It is important that these workflows be improved and updated over time to allow the company to maintain its competitive advantage. However, we find that the course of the above two workflows is due to changes in the managerial workflow component.

Managerial workflow governs the entire administrative and operational workflows. It is executed through strategic decision-making, and this strategic execution is driven by business operation planning, change management and outcome evaluation. In the execution of the managerial workflow component, it collaborates with the administrative workflow component and operational workflow component. The managerial workflow component is the primary cause of the dynamic workflow changes of an organisation. We believe that the managerial workflow is usually unstructured, dynamic and the process changes over time and is driven by market pressure, economic competition and business value; therefore, managerial workflow is dynamic, flexible and sometimes ad-hoc. Therefore, if we make the administrative and operational workflow components flexible, this in turn produces managerial workflow changes; the administrative workflow and operational workflow component can be automatic or semi-automatic changes. We have found that no work exists in the current literature of modelling dynamism of the managerial workflow. However, some work exists in modelling flexible workflow that can deal with changes in literature close to administrative workflow and operational workflow, (Aalst, W.M.P. van der., 1998; Bar-Yam B. 2004; Berman, F., Fox, G. & Hey, A., 2003;

6.5 WORKFLOW MINING THOUGH MAO MODEL

The decisions in an organisation are often made by the strategic or senior management board. The decision usually breaks down the structures of the workflow that are in execution. Therefore, from the scientific perspective, it is represented as unstructured data that is passed on to the collaborative division workflow management. The workflow management works on the structured information and relationships. We propose that if the decision to change (data) is unstructured, the workflow management system needs to convert this data into structured data through a **pre-process of unstructured data management** (PP-UDM), a process of mining, organising and analysising to extract actionable information. We propose PP-UDM as a tool to help mine the workflow change, and help convert the unstructured information into structured by considering precision, thoroughness and relevance of the unstructured information provided.

The key management issue is to manage the change. Change is caused by a decision. A decision usually changes the existing structure. Workflow is under control if the workflow is structured business processes, information and data. Change to a workflow cannot be made in an ad-hoc fashion. In order to be able to manage the change, we must pre-process all un-structured information, and then update the workflow. Therefore, we propose a workflow mining that undergoes the pre-processing of unstructured information to structured, using workflow log to mine the changes.

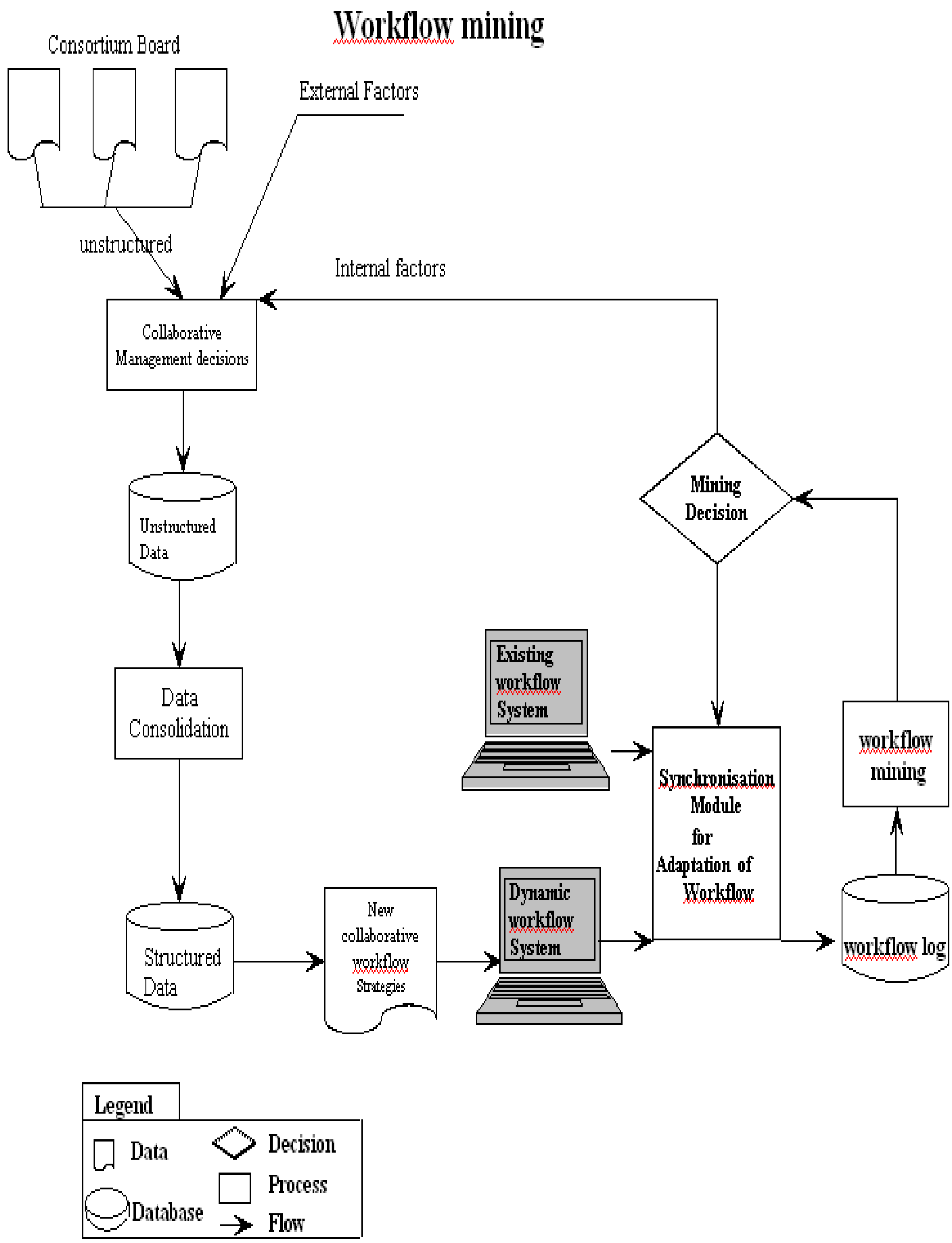


Figure 6-5: Workflow Mining through Pre-process UMD and Workflow-log

Creating workflow processes is complicated and time consuming as per the requirements of management. To support the continuous change management and design process, we propose using a **workflow log** which contains information about the workflow processes, information collected at runtime and can be used in the diagnosis and re-design phases to derive a model explaining the events recorded in workflow mining. Internal factors are passed on for further consideration in the decision-making processes by the management; otherwise, it is a cyclic process in creating a new workflow model from the existing workflow.

6.6 WORKFLOW MINING IN LOGISTICS WAREHOUSE

Logistics warehousing is an industry which involves the storage of goods in a warehouse. The goods can be general goods, or dangerous goods, climate-controlled goods or frozen goods etc. The movement of goods in and out of a warehouse is done through logistics pick-up and drop-off operations.

We use the MAO model to act as a generic workflow management model. As part of a common understanding of the workflow policies and procedures within an organisation such as a warehouse logistics company, the management system must contain a commonly agreed conceptual knowledge of operation model, administrative model and management hierarchy, and provides an architectural separation of business functionality as well as workflow implementation. This not only facilitates a higher level understanding of the complex collaborative workflow, but also gives the workflow designers or experts the business rules defined in a UML model to implement such systems.

The model has three distinct components: technical and communication layer forms the data store for an enterprise, the synchronisation component consisting of synchronisation and monitor, and on top of these layers is the framework and networking layer which provides services to individual companies within the consortium through web services. This flexibility is useful in a collaborative environment as the business models may also undergo change from time to time as some companies may no longer want to be part of the consortium and new companies may want to join the consortium.

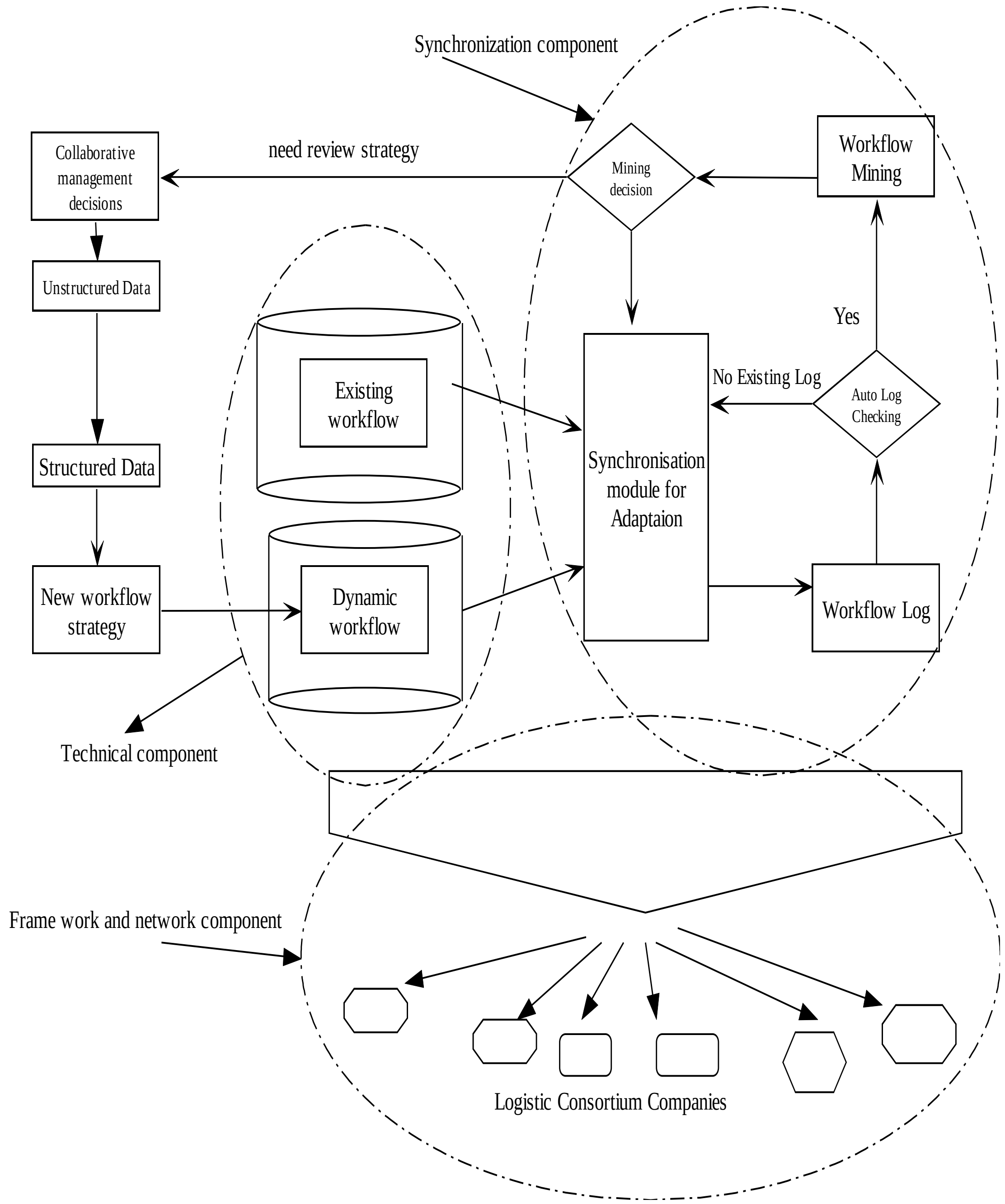


Figure 6-6: Workflow Mining in a Logistics Warehouse Industry

The advent of the technology, the connectivity, and information richness produces an increasingly dynamic business environment and requires collaborative workflow. Workflow mining is necessary to mine the sequence of activities and log books. The purpose of a collaborative workflow is to work together towards organisational-defined goals and any changes have to be made in the interests of the organisational goals, and this requires structured change and update rather than ad-hoc changes.

6.7 CONCLUSION

In this chapter, we presented the MAO Model for intra-organisational workflow management. The key management issue is about the management of change. In order to support the management of change, we proposed workflow mining through the pre-processing of unstructured decisions or information, to convert these to structured, followed by update workflow and monitoring the workflow through workflow logs.

Chapter 7 - Inter-Organisation Workflow Modelling

7.1 INTRODUCTION

As the process of business becomes more complex, one has to manage it so that a work process can achieve maximum efficiency. The aim of the inter-organisation workflow management is to maximize the efficiency of a collection of work processes. As the workflow paradigm continues to infiltrate organisations, we need to cope with complex business processes in multi-organisation partnership or alliances environments; hence, the inter-organisation workflow management system will become a fundamental building block for partnership success.

7.2 INTER-ORGANISATION COLLABORATIVE WORKFLOW

As defined in Chapter 4, the Inter-organisation collaborative workflow is defined as the collaboration of a group of companies working together towards common goals

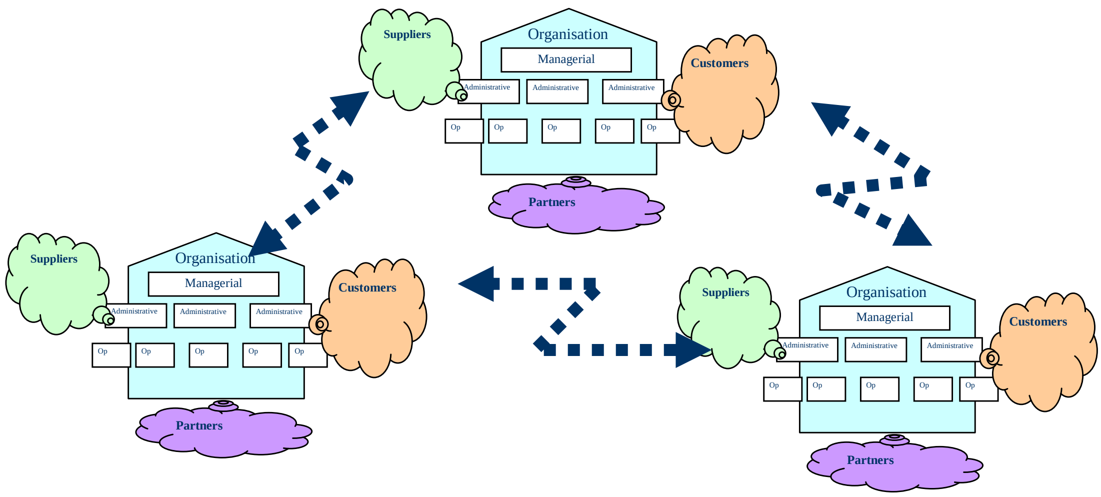


Figure 7-1: Inter-Organisation Collaborative Workflow

7.3 PETRI-NETS

Petri-nets are not a new concept. However, their application to the modelling of the collaborative workflow in an inter-organisational environment is relatively new and difficult to do, because of the complexity of the diagrams and the complexity of the workflow itself. We find that for a small process or small parallel processes, the Petri-nets work very well. However, when the system becomes large-scale, it is difficult to use Petri-nets to represent all the process. In this chapter, we propose the use of Petri-nets to model inter-organisation collaborative workflow.

7.3.1 **Concepts of Petri-nets**

Petri-nets are formalisms for modelling dynamic systems. They are graphical, mathematically formalized, and able to be analysed. The original nets were developed by Cruz, S. M. S., Campos, M. L. M., Pires, P. F. & Campos, L. M., 2004.]; later, various extensions were developed, providing new modelling constructs. Some of these extensions provide easier modelling retaining the same expressiveness as classical Petri-nets, although some provide more expressiveness (Denning, P.J., 1994). Petri-nets have been applied to a large number of areas, including communication protocols, performance evaluation, and distributed systems (Clark, M., 2002) because they are very general and were the first to model concurrency (Berman, F., Fox, G. & Hey, A., 2003).

7.3.2 **The Notation Systems**

Petri-nets use transitions which involve several input and output states. The classical Petri-net model is a network composed of places (O) and transitions (|). Connections (arrows) are directed and between a place and a transition. Tokens (●) are the dynamic objects. The state of a Petri-net is determined by the distribution of tokens over the places. Firing is to enable transition. Firing corresponds to consuming tokens from the input places and producing tokens for the output places and firing is atomic.

7.3.3 **The Firing Rules**

The rules for executing the system are:

- A transition is 'active' when each of its input places contains a token.
- Each active transition in the diagram is 'fired' by removing 1 token from each input place and generating one in each output place.
- A Change of State …is denoted by a movement of *token(s)* (black dots) from place(s) to place(s); and is caused by the *firing* of a transition.
- The firing represents an occurrence of the event or an action taken.
- The firing is subject to the input conditions, denoted by token availability.
- A transition is *firable* or *enabled* when there are sufficient tokens in its input places.

After firing, tokens are transferred from the input places (old state) to the output places, denoting the new state. Petri-net diagrams allow representation of all the elements included in a workflow model: roles, transitions, events, control and information flows, conditions and relevant data. They can also model concurrent events by making use of a synchronisation bar to specify the forking and joining of parallel flows of control.

7.3.4 **Petri-nets modelling for Vending Machines**

Figure 7.1 shows an example of vending machine on the left hand side and the representation of tokens in the Petri-net diagram on the right hand side. We assume the machine dispenses two kinds of items for children - a ball and doll for 20c and 15c, and only two types of coins can be used – 10c coins and 5c coins; the machine does not return any change. It shows various inputs which are possible for an output to be either a ball or a doll.

Scenario 1: Deposit 5c, deposit 5c, deposit 5c, deposit 5c, returns 20c doll.

Scenario 2: Deposit 10c, deposit 5c, returns 15c ball.

Scenario 3: Deposit 5c, deposit 10c, deposit 5c, returns 20c doll.

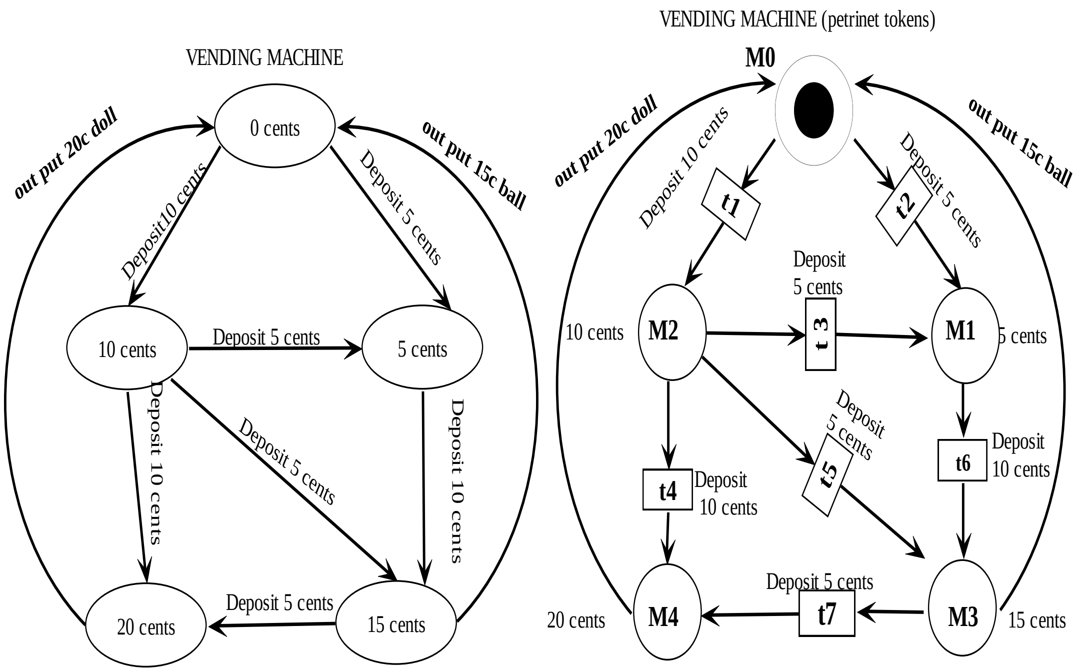


Figure 7-2: Petri-nets Modelling of a Vending Machine

$$M0 \xrightarrow{t1} M1 \xrightarrow{t3} M2 \xrightarrow{t5} M3 \xrightarrow{t8} M0 \xrightarrow{t2} M2 \xrightarrow{t6} M4$$

Figure 7-3: A Firing or Occurrence Sequence

A *marking* is a state ... Initial marking:M0

M0 = (1,0,0,0,0)

M1 = (0,1,0,0,0)

M2 = (0,0,1,0,0)

M3 = (0,0,0,1,0)

M4 = (0,0,0,0,1)

Petri-nets have some behavioural properties such as:

1. Reachability

"Can we reach one particular state from another?"

"M2 is *reachable* from M1 and M4 is *reachable* from M0."

In fact, in the vending machine example, all markings are reachable from every marking.

2. Boundedness

"Will a storage place overflow?"

A Petri-net is said to be *k-bounded* or simply *bounded* if the number of tokens in each place does not exceed a finite number *k* for any marking reachable from M0.

The Petri-net for vending machine is 1-bounded.

A 1-bounded Petri-net is also *safe*.

3. Liveness

"Will the system die in a particular state?"

A Petri-net with initial marking M0 is *live* if, no matter what marking has been reached from M0, it is possible to ultimately fire *any* transition by progressing through some further firing sequence.

A live Petri-net guarantees *deadlock-free* operation, no matter what firing sequence is chosen.

The vending machine is live and the producer-consumer system is also live.

A transition is *dead* if it can never be fired in any firing sequence.

The advantages of Petri-nets are they have formal analysis to ascertain the correctness of the workflow. By using the formal analysis, we can determine whether a workflow model contains any deadlocks or live-locks.

7.4 COLOURED PETRI-NETS

7.4.1 The Concepts

Coloured Petri-nets have got their name because they allow the use of tokens that carry data values and can hence be distinguished from each other – in contrast to the tokens of low-level Petri-nets, which by convention are drawn as black, 'uncoloured' dots. In the beginning, only small, unstructured sets of colours were used to enumerate, for example, a fixed set of processes. Later it was realized that it was possible to generalize the theory and the tools, in such a way that arbitrarily complex data types can be used as colour sets. Today it is not at all atypical to have tokens that carry a complex data value, such as a list of many thousand records, involving fields of many different types. There is no longer any difference between a colour set and a type, and no difference between a token colour and a token value, but for an event to be able to occur, a transition must have sufficient tokens on its input places, and these tokens must have token values that match the arc expressions.

7.4.2 Extended Coloured Petri-nets Notations

The Petri-nets diagram is used for modelling the dynamic aspects of systems; they show the flow of control from one transition to another transition. The transition is triggered by one or more events and the transition may result in one or more events that may trigger other transitions or processes. Events, which are message flows, start from the token being at the beginning and end with the token at the finish state, having transitions in between connected by events. Petri-nets diagram can be thought of as defining the actions in that process which continue until everything that needs to be done, is done. Petri-net diagrams represent the decisions, iterations and parallel/random behaviour of the processing. A common use of the Petri-net diagram is to model the dynamic aspects of a system. When we model the details of the dynamic aspects of a workflow computation, we focus on transitions as viewed by tokens that capture the flow of control.

Petri-nets also provide a very useful technique for modelling a workflow called swimlane. A swimlane is a group that represents the business organisations, which are responsible for activities. Therefore, by having a swimlane, we partition the transition states on a Petri-net diagram into groups. This technique gives us benefits in modelling and reading a workflow.

By adopting the idea from the Petri-net diagram of UML, we try to extend it so that it will help us to solve our initial problem.

In this section, we suggest that a workflow model should contain the following objects:

Data: represents the data that will be used or produced in an action (e.g. e-mail, order form)

Conditions: represents the conditions associated with an action. Conditions can be divided into two kinds, namely *pre-conditions* and *post-conditions*. Pre-conditions are conditions that need to be satisfied so that an action can be enacted. Post-conditions are conditions that need to be satisfied on completion of an action.

Action: represents a piece of work, it can be manual action or automatic action.

Worklet: represents an activity/business process that is carried out by an organisational unit (e.g. department).

7.5 CASE STUDY: USING COLOURED PETRI-NETS TO MODEL THE LOGISTICS CONSORTIUM

In this case study, we use the Petri-nets diagram to model the dynamic aspects of systems; they show flow of control from one transition to another transition. The transition is triggered by one or more events and the transition may result in one or more events that may trigger other transitions or processes. Events, which are message flows, start from the token being at the beginning and end with the token at the finish state having transitions in between connected by events.

7.5.1 Problem Description

A Logistics Consortium (LC) consists of many logistics partners. Here we present five small-medium logistics operators that work together to deliver the services and goods. There are: one warehouse operator (storage of goods for customers), one logistics operator (scheduling pick-up and delivery with many transporters), a third party banker, a customer service provider (customer or client interaction and management of complaints) and a transporter (driver who owns a truck or vehicle).

Each operator has its own responsibilities; however, they are connected to each other. The warehouse operator now already has its own computerized warehouse management system, as does the banker.

Currently, the workflow of the logistics management is not integrated into the existing Warehouse Management System (WMS) or the banker system. Co-ordination and delivery of goods are initiated by customers using traditional means of transmitting requests either by telephone or fax. The shared collaborative workflow system uses spreadsheets to manage and update the delivery and transportation charges. The information is fed manually to the banker for necessary updating of the payment from the customer, service providers and the like [9].

All these works still use a lot of paper work, and are largely physically done, which is time-consuming and prone to error. The complexity of works becomes greater and greater as customers' orders increase. It is hard to keep track of the progress of the orders. The logistics manager has to go down to the warehouse floor to check on the movement of goods or transportation congestions. It is also difficult to schedule the transporters (trucks), and manpower, etc. Due to all these issues, LC wants to change the way it is doing business. LC wants to change its inter-organisational workflow (flow of work among the operators) and its customers (flow of jobs to its customers). LC would like to use computers to handle most of the document communication automatically, and all the movement of papers or documents from one operator to another operator. LC also wants its customers to be able to book warehouse and logistics services, place orders, view the status of orders, etc. on the Internet. This is more like an e-commerce way of doing business. Figure 7.4 shows the case study example used in this thesis about warehousing operations.

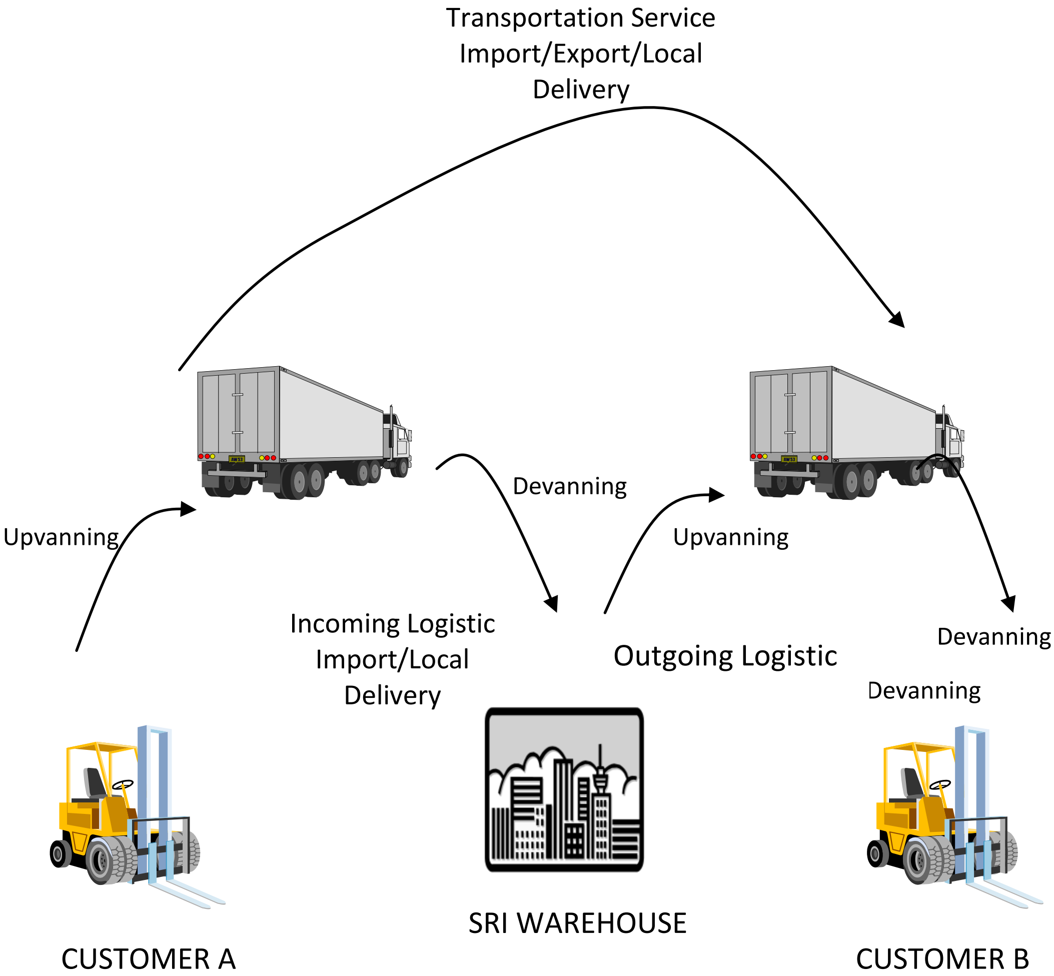


Figure 7-4: Case Study of a Warehouse Services

7.5.2 **Coloured Petri-nets Modelling**

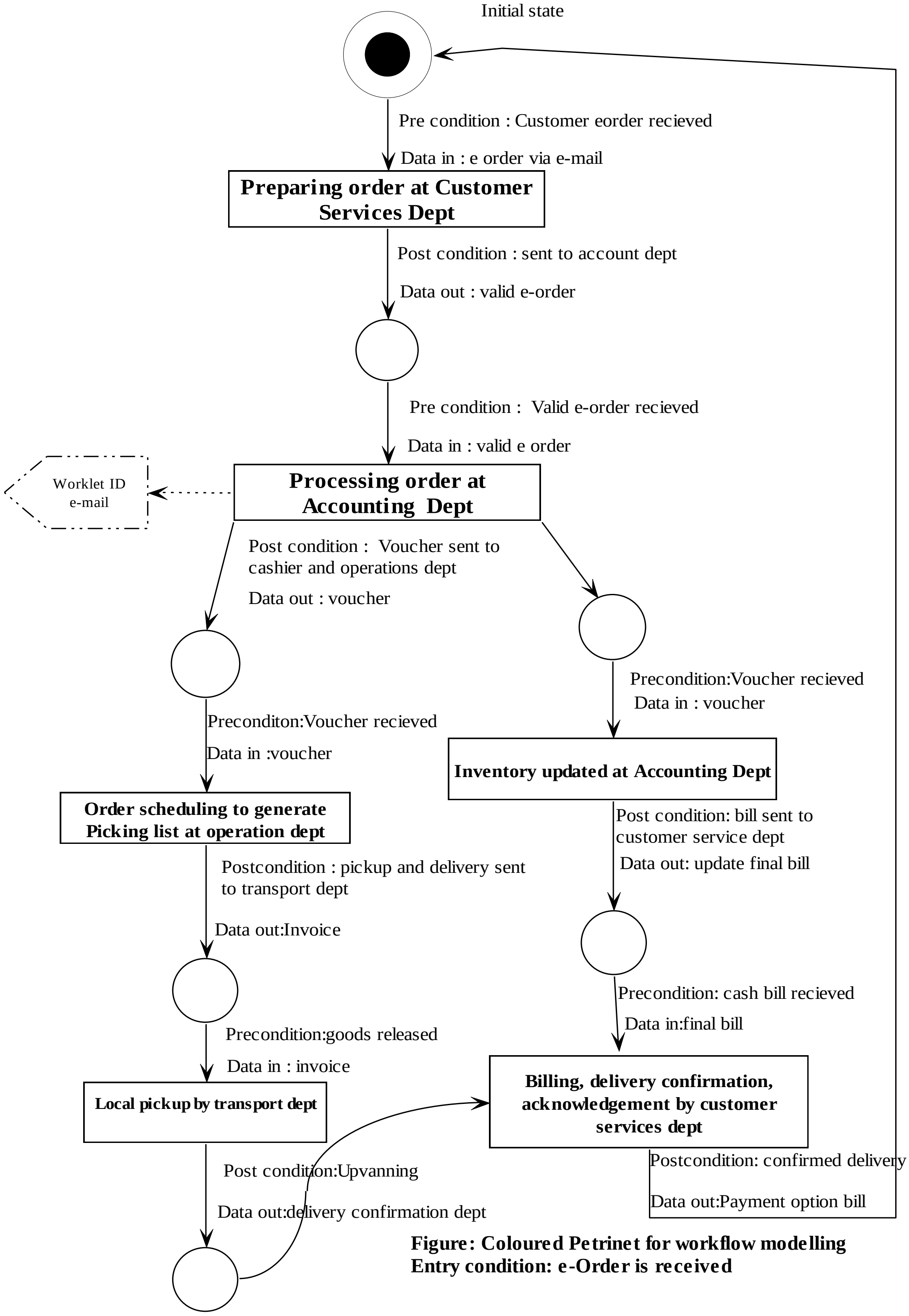


Figure 7-5: Colour Petri-net for Workflow Modelling

Warehouse Operations are managed through workflow management system (software). All the tasks including order, accounts, scheduling, pick-up, delivery, and confirmation are done automatically by the system communication with operators and operation departments. After sending the copy of e-Order, the CS-Dept worklet then reaches the finish state. The entry condition of the CS-Dept worklet is an e-Order received from a customer by the system. For convenience, the WorkletID for CS-Dept is 0001. The logistics department has many duties here. The first one is to decide if LC wants to accept or reject the order. An order can be rejected for several reasons. For example, Customer A wants to export 20 tons of chicken wings to Customer B, however, when the logistics department checks the warehouse database, Customer A has only 10 tons of chicken wings. Therefore, the e-Order has to be rejected. The logistics department then sends a rejection letter to the customer along with the reason and the worklet reaches the finish state. If the customer is on the Internet this notification would be done by e-mail. If the e-Order is accepted, the logistics department will send an acceptance letter and the next task is to book trucks for delivery. The logistics department sends all the information about the delivery, date of delivery, type of truck, etc. From here, we are waiting for confirmation from the Transportation Department. Once the confirmation is received, the logistic department then reports to the customer that the order is confirmed.

Next, the logistics department will notify the warehouse department to prepare the manpower and the goods for the upvanning process. After that, it completes a charges form (from staff web site) and sends it to the accounts department. The worklet then reaches the finish state. We assign 0002 as the WorkletID for the logistics department. The entry constraint for it is an e-Order received from the customer service department. The whole process is represented using colour place transition Petri-nets format as shown in figure, Place p0 represents the starting place (source) for the Coloured Petri-nets (CPN). Tasks represent a processing entity—here it is the customer services department which accepts the customer e-order if the pre- and post-conditions are met before the firing takes place. When the firing takes place, the token is in place 1. Here the pre-condition is that a valid e-order is sent and the post-condition is that the voucher is sent to two sections, the accounting and operations departments, for the firing of tokens to take place. Here we satisfy the condition of the place transition net that tokens in every place are greater than the weight ie value shown on the arrows. That task also acts as an Or-Split, a decision task, which after processing can control the direction of flow. At inventory update, accounts department transition t3 occurs when the pre-condition and post-condition of receiving the voucher and the bill sent to the customer services department are satisfied. Parallel transition for operation department token are fired when pre and post conditions of receiving a voucher and delivery schedule sent to transport department are met. The next transition is t4 which is local pick-up; then the transition stage is notification and a delivery acknowledgement is sent by the customer department.

The method we like to compare is the Petri-Net approach. Petri-nets have been used for workflow modelling by many researchers and it is a very good method. In fact, there have been many variants of Petri-nets intended to support workflow modelling. Variants include Workflow Nets (Denning, P.J., 1994), (Dillon T, Tan P.L., 1993) and Coloured Petri-nets, (Duong, D.D., Boley, H., Le, T.T.T., Bhavsar, V.C., 2006).

Unfortunately, not many people, system architects or developers understand it easily and directly. The advantages of Petri-nets are that they have formal analysis to ascertain the correctness of the workflow. By using the formal analysis, we can determine whether a workflow model contains any deadlocks or live-locks.

Figure 7.6 shows the Petri-Net version of the CS-Dept worklet. The bubbles represent actions and the rectangles represent the transition. The black circle inside the bubble represents a token. A token moves from one bubble to other bubbles and a bubble can have many tokens. One could say that tokens are similar to conditions.

As we can see in the diagram, there is no representation for who is doing each task (actor). Moreover, in the Petri-Net diagram, there is no representation of flow of data.

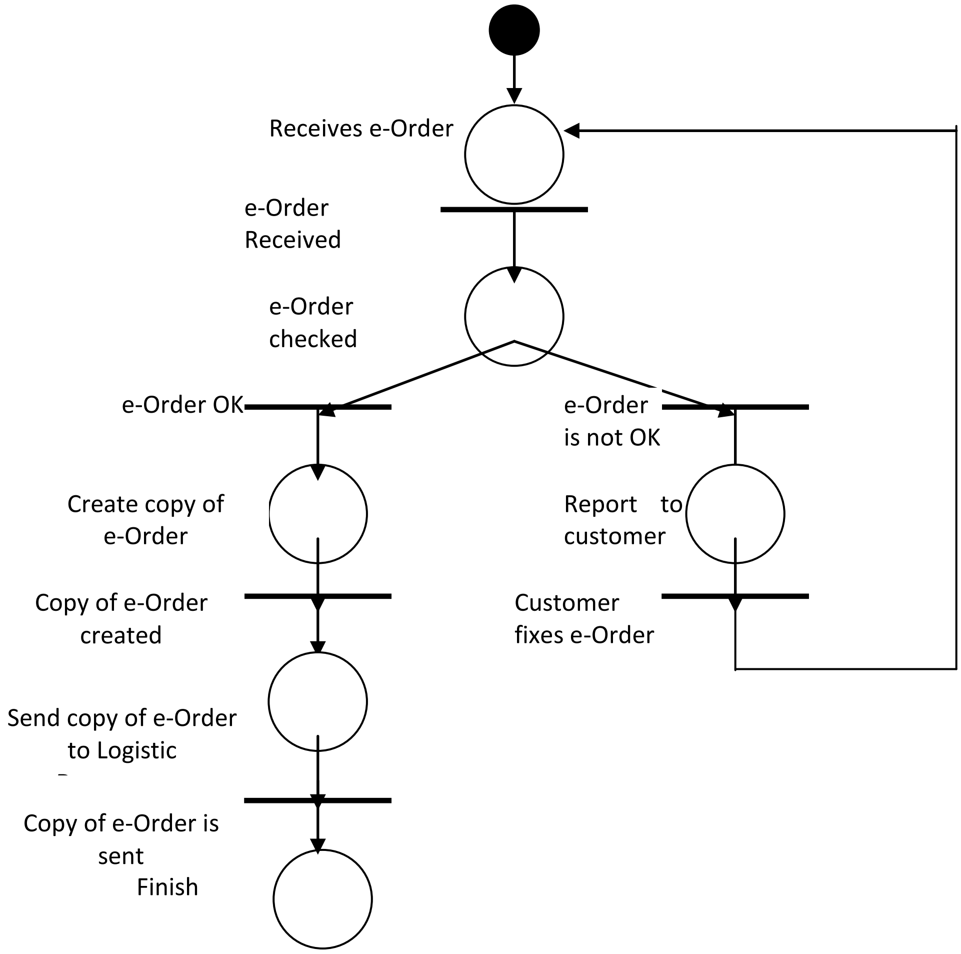


Figure 7-6: Petri-net Version of CS-Dept Worklet

7.5.3 **Customer Logistics Service**

Figure 7.3 shows the Petri-Net version of the CS-Dept worklet. The bubbles represent actions and the rectangles represent the transition. The black circle inside the bubble represents a token. A token moves from one bubble to other bubbles and a bubble can have many tokens. One could say that tokens are similar to conditions. By mapping tasks to transitions, resources to places, and cases to tokens, the three dimensions of the workflow space can be faithfully represented using this formalism. If colour is added to a classical Petri-net, workflow attributes can also be included in the model. That is, in a colour-extended Petri-net, conditions can be set for the values of the tokens. Time is another extension of the classical PN. By adding time, a complete model of a real workflow system can be delivered. Lastly, hierarchical extension enables the hierarchical structure of the workflow process model to be preserved. In the next section, we further discuss Petri-net diagrams and we propose to extend them so that they are suitable to model a flexible workflow model.

7.6 SYNCHRONOUS, ASYNCHRONOUS COLLABORATIVE WORKFLOW

The advent of the web has bound organisations together for carrying out sales over great distances and at any time; it has created new modes for marketing and enabled partnerships, and collaboration previously inconceivable within a wide array of businesses, as well as other human activities (Aalst, W.M.P. van der., 1997).

7.6.1 Synchronous, Asynchronous, and Forced Synchronous Workflows

When designing a workflow process, one must decide whether it is to be executed as a synchronous, asynchronous, or forced synchronous process. The process design affects the amount of time it takes for the Workflow Engine to return control to the calling application that initiates the process.

Synchronous--A synchronous process contains only activities that can be executed immediately, so that the Workflow Engine executes the process without interruption from start to finish. The Workflow Engine does not return control to the calling application until it completes the process. With a synchronous process, you can immediately check for process results that were written to item attributes or directly to the database. However, the user must wait for the process to complete. If the process takes a long time, the application may appear to hang. In this case, you should change the process to an asynchronous one.

Asynchronous--An asynchronous process is a process that the Workflow Engine cannot complete immediately because it contains activities that interrupt the flow. Examples of activities that force an asynchronous process include deferred activities, notifications with responses, blocking activities, and wait activities. Rather than waiting indefinitely when it encounters one of these activities, the Workflow Engine sets the audit tables appropriately and returns control to the calling application. The workflow process is left in an unfinished state until it is started again, usually by the Notification System, Business Event System, or the background engine. With an asynchronous process, the user does not have to wait for the process to complete in order to continue using the application. However, the results of the process are not available until the process is completed at a later time.

Forced synchronous--A forced synchronous process completes in a single SQL session from start to finish and never inserts into or updates any database tables. As a result, the execution speed of a forced synchronous process is significantly faster than a typical synchronous process. The process results are available immediately upon completion. However, no audit trail is recorded. One may want to use a forced synchronous process if the application needs to generate a specific result quickly and recording an audit trail is not a concern. To create a forced synchronous process, the item key of the desired process must be set to #SYNCH and follow certain restrictions in designing the process, such as not including any notification activities (Xiao Feng, J., Junhua, X., Hua, Z. & Zuzhao, L., 2003).

A consequence of this connectivity and information richness is that one is faced with an increasingly dynamic business environment and marketplace. This environment requires a significant collaborative workflow. A workflow is a sequence of activities that produces a result of observable value. A collaborative workflow focuses on the process of working together towards common goals. They can range from a small group of companies, project-oriented research teams, to widely dispersed industries with common interests. Effective use of collaborative workflow is now considered a vital element in the success of enterprises of all kinds. Workflow can be represented by a sequence diagram, a collaboration diagram, Petri-net or an activity diagram [5]. This IT support has expanded with the advent of e-commerce. However, with this advancement of B2B (Business to Business) and P2P (Partner to Partner) e-commerce (Alston, J., Hess, D. and Ruggieo, R., 2002), there has been an increasing tendency to set up consortia that represent several players in a given field. These consortia consist of companies or organisations that get together and produce a single site or what appears to be a single site in order to increase traffic through the site compared to other competitors' sites and/or extend beyond their region of operation. Similarly, at the back-end, these companies need to have a back-end system which needs to be integrated to efficiently work towards meeting their consortium obligations, but a mere enumeration of all workers, activities and artefacts does not quite constitute a process. We need a way to describe a meaningful sequence of activities that produce some valuable result, and to show interactions between processes. A consortium's individual company consists of many departments. Generally there are six operational divisions or departments: management, warehouse t, logistics, accounts, customer service and transport t. Each department has its own responsibility; however they are connected to each other. The warehouse department now already has its own system, as does the accounts department. The complexity of works increases as the customers' orders increase. As it is hard to know the progress of the orders, warehouse check and it is also difficult to schedule the trucks, manpower, etc. a consortium may wish to change its internal work (flow of works among departments) and its external work (flow of works with its customers and other collaborative organisations), and to integrate various departments with other logistics network companies in its consortium. Consortium also wants its customers to be able to book warehouse service, logistic service, place orders and view the status of orders, etc. on the Internet. This is more like e-commerce. Aalst, W.M.P. 1999 provides a typical e-solution for collaborative workflow.

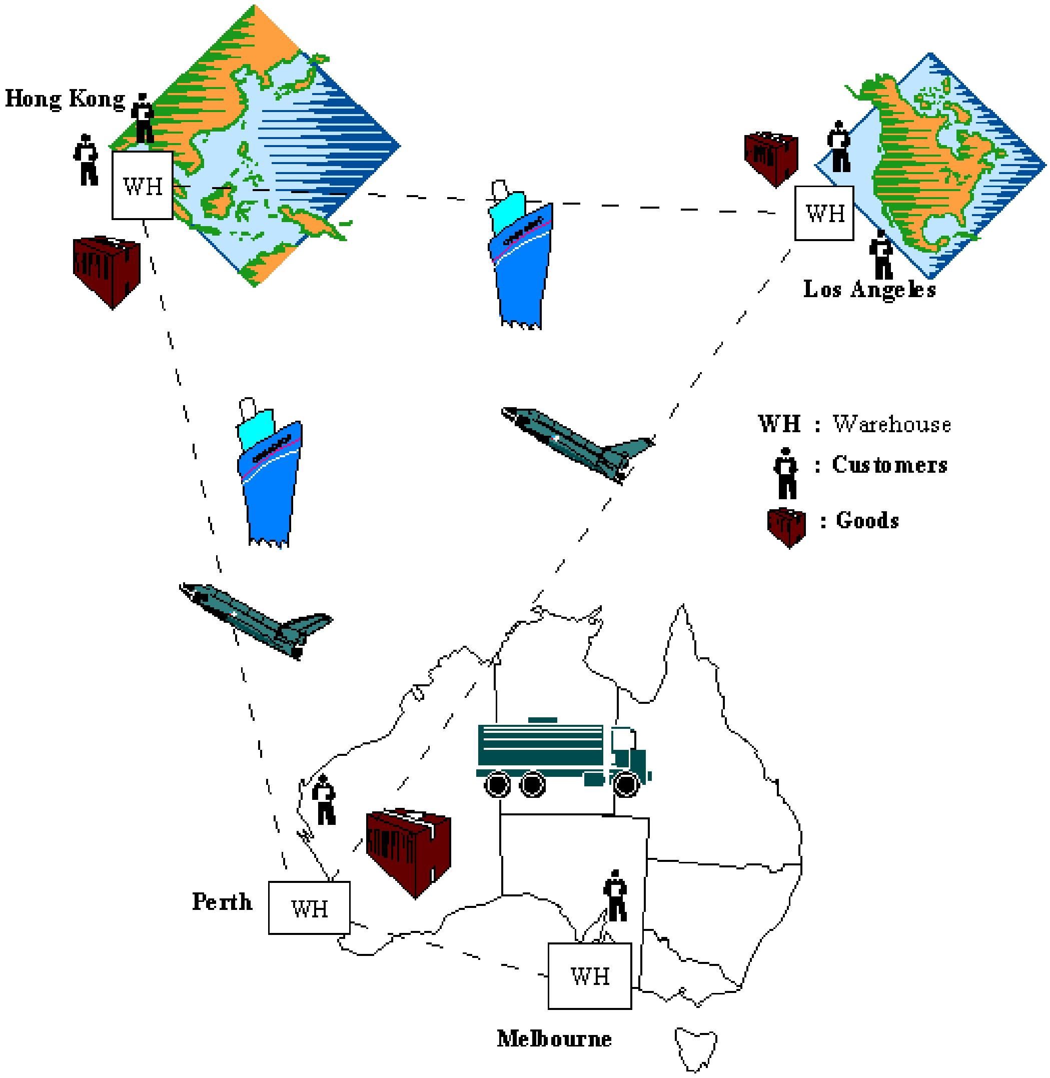


Figure 7-7: Global Collaborative Logistic Companies' Network

7.6.2 **Challenges in Synchronous and Asynchronous of Collaborative Workflow**

In this section, we lay out the challenges in modelling the synchronous and asynchronous of collaborative workflow:

1. Implementation aspects of integration and adaptation of changes in the new workflow into an already existing workflow:

2. Information systems that can change at runtime; hence, a new workflow should be able to synchronize with existing workflow to adapt quickly; and

3. Other issues include:

a. Management of data scattered over multiple origin systems/legacy systems; for example, a company will have consolidated data in one logical view with a unified architecture, thereby enabling data-source independence. Because application data continues to live and change in the original systems, the new software layer must be able to retrieve origin data on the fly and also propagate changes back to the original systems.

b. Providing support for transactions/interactions across multiple back-end systems. "The hard part is getting a transaction model wrapped around those back-end systems; so if it didn't work in the third system, it was able to roll back in those first two systems," (Chang, E., Dillon, T.S. & Hussain, F., 2005).

These challenges will help to create a uniform data processing environment for the whole enterprise, which would lead to changes and improvements in customer services, control of receivables and increase efficiency in communication, sales, marketing and minimization of warehouse stocks, streamlining inventory and logistics flows.

It will also enable consortium management to monitor the collaborative enterprise's condition, its stock, orders and its general financial condition on a routine basis. This is indispensable to the management processes and enhances decision-making and changes which need to be made in the short- term and long-term in order for the consortium to compete in the global market.

7.7 CONCLUSION

The main concepts of our diagram are colours and firing rules. The problems, issues arising due to the colour (conditions) and the ability to fulfil the conditions as they arise without delay, is a benefit often attributed to synchronous communication. In this chapter, we discuss Petri-nets modelling for dynamic business processes of large logistic consortia. Often, we see that the business processes consist of two parts: a structured operational part and an unstructured operational part. We call these workflow control components and business control components, or they could consist of semi-structured parts with some given and some unknown details. Unpredictable situations may occur as a result of changes in decisions made by the management. The inability to deal with various changes greatly limits the applicability of workflow systems in real industrial and commercial operations. This situation raises problems in workflow design and workflow systems development. We propose workflow adaptation methodology through the process of component integration techniques for the development of new workflow using existing workflow components.

Chapter 8 - Service Oriented Inter-Organisational Workflow Management

8.1 INTRODUCTION

Consortia or alliances can be small group of companies, project-oriented research teams, to widely dispersed industries with common interests. Effective use of collaborative workflow is now considered a vital element in the success of enterprises of all kinds. Workflow can be represented by a sequence diagram, a collaboration diagram, Petri-net or an activity diagram Alston, J., Hess, D. & Ruggieo, R., 2002. This IT support has expanded with the advent of e-commerce. However, with this advancement of B2B (Business to Business) and P2P (Partner to Partner) e-commerce, there has been an increasing tendency to set up consortia that represent several players in a given field. Such consortia consist of companies or organisations in a given field that get together and produce a single site or what appears to be a single site in order to increase traffic through the site compared to other competitors' sites and/or extend beyond their region of operation, but a mere enumeration of all workers, activities and artefacts does not quite constitute a process.

8.2 THE MAO MODEL FOR INTER-ORGANISATION WORKFLOW

Collaborative Workflow for an Extended Enterprise

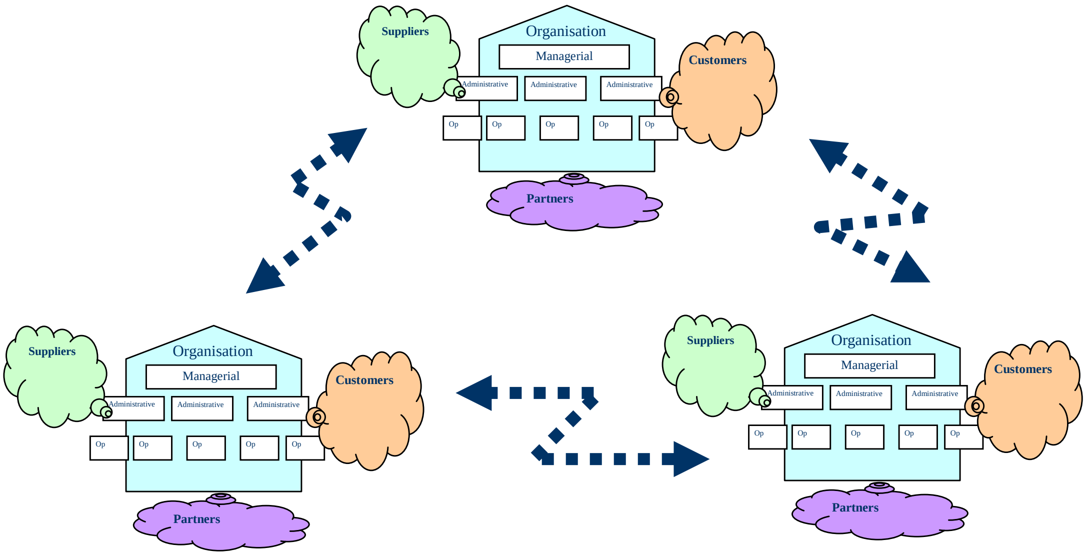


Figure 8-1: Collaborative Workflow for Extended Enterprise

Collaborative workflow is a new type of workflow that allows an organisation or enterprise to be added to the existing workflow model and be used in the extended organisation or enterprise. The advent of the Internet has provided mechanisms for binding organisations to work together; therefore, they need collaborative workflow management for carrying out sales over great distances and at any time. Collaborative workflow is important for marketing and enabled partnerships, previously inconceivable within a wide array of business, as well as other human activities. Management of collaborative workflow promotes connectivity and information richness that is characteristic of an increasingly dynamic business environment and workflow. Collaborative workflow management helps the shift from old business paradigms to new business paradigms. New collaborative organisation workflow systems *transcend* the *previous static, closed, competitive models* and *move* to *dynamic open re-configurable, often collaborative models* that are able to respond to the business environment dynamics inherent within the networked economy (Tsaparas, P., 2004, Ulieru. M., et al. 2000), (Ulieru. M, Stefanoiu. D., 2000). Several factors characterise collaborative workflow management for extended enterprise, namely:

1. A strong information infrastructure that extends beyond the original closed walls of the *individual enterprise*.

2. High connectivity and electronic handling of information, of all sorts including data and documents.

3. An increasingly *collaborative approach* between what were more traditional *individual enterprises*.

4. Utilisation of new forms of electronic interaction, provision of services and utilisation of services.

5. Ability to self-organise and reconfigure the business of the organisation, perhaps even the organisation as a whole.

6. Use of multiple channels for sales and marketing.

7. Capture and utilisation of business intelligence from data and *smart information use*.

These features are increasingly exhibited by successful modern business organisations, for instance, in collaborative supply chains, collaborative consortia for marketing, strategic partnerships, alliances and selling services, utilisation of web sales, marketing and customer service and creation of multiple modes of user interaction with the business.

A key factor in the success of such collaborative workflow management for extended enterprise is the creation of the underpinning information infrastructure to carry out the required services and development to enable and support the creation and the strengthening of small-medium enterprises (SMEs) to achieve some of the characteristics of collaboration. However, current workflow techniques do not address the collaborative workflow issues and management.

This chapter aims to develop the semi-automated modelling approach for dynamic business processes for large logistic consortia, where business strategies can be captured vigorously while simultaneously allowing workflow changes to be handled. Often we see that the business processes consist of two parts: a structured operational part and an unstructured operational part; or they could have semi-structured parts with some given and some unknown details. Unpredictable situations may occur as a result of changes by management. The inability to deal with various changes greatly limits the applicability of workflow systems in real industrial and commercial operations. This situation raises problems in workflow design and workflow systems development. We propose a prototype for workflow modelling and workflow mining techniques for the adaptation of workflows to the existing workflow system.

8.3 SERVICE-ORIENTED FRAMEWORK FOR COLLABORATIVE WORKFLOW MANAGEMENT

We proposed a conceptual model of a service-oriented framework for collaborative logistics companies (*Computers & Operations Research*, 2001).. The framework has four layers:

1. Framework Layer
2. Network Layer
3. Communication Layer
4. Technical Layer

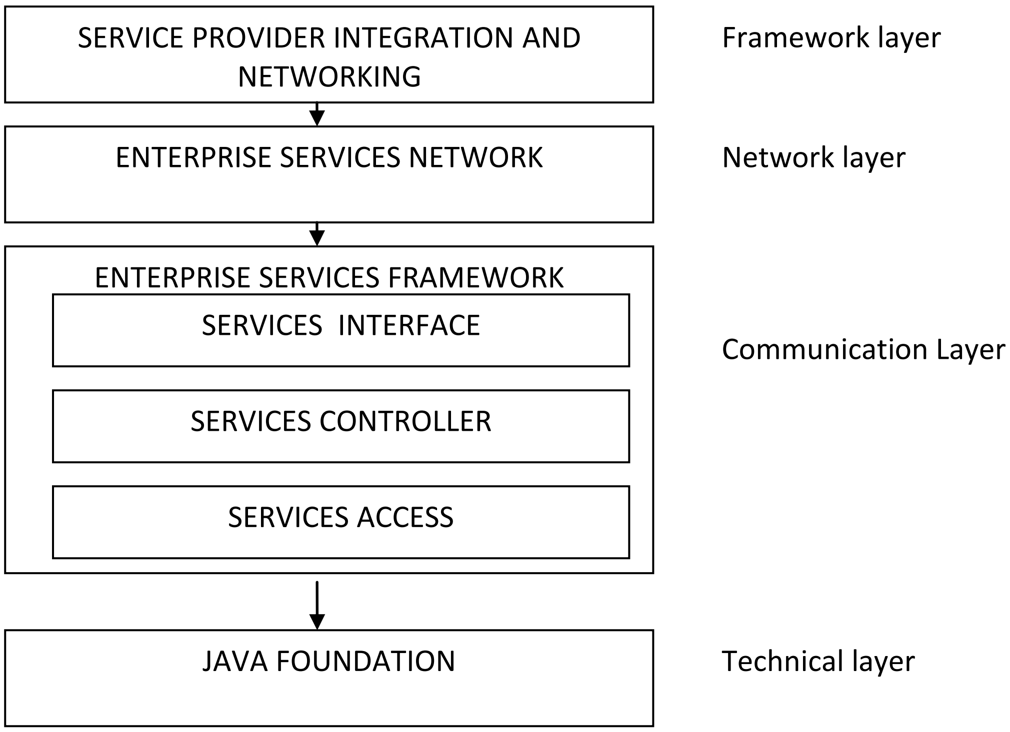


Figure 8-2: Enterprise Model Framework

It is the job of the HTTP server adaptor to communicate with a given HTTP server and forward requests to one or more application 'instances' - an instance is a separate copy of a given application process. An enterprise services framework serving a few users may have only one instance. A large application may have tens or hundreds of instances running on one or more machines. If an application has more than one instance, the enterprise services framework controller is essentially acting as a load balancing agent. If an instance fails, it affects only that particular instance – all other instances and/or the site's web server is unaffected. The controller will forward requests over the network as easily as it will forward requests to applications running on the same box as this separation allowed designers to use business rules defined in a UML model to drive four distinct steps in implementing such systems.

Step1 Create two platform independent models in UML. The first model is a generic domain model, used to build a common understanding and vocabulary among warehouse Logistics domain experts.

Step2 The domain model is then mapped into a second platform-independent model (PMI) representing warehouse logistic business. Each of the models includes a detailed set of UML Class Diagrams, Use Cases and associated Activity Diagrams describing the system (Brandenburger, A. M. et al. 1996).

Step3 Using this business model, we can create one or more subsystems to represent the logical functions of each of the enterprise systems. This business model contains both the details of the business logic, as well as the mapping of the logic into the major subsystems. The business model forms the basis for managing all changes to the current systems.

Step4 System Integration using Conceptual Model of Platform Specific Models (PSM's), for each of individual systems to form enterprise system. These models were each derived from one or more subsystems in the business model. The relationships are shown in Figure 8.3. System construction consists of customizing each of the enterprise systems, and creating the business logic. Business logic that spans systems is constructed using components technology and deployed in the application server (Brandenburger, A. M. et al., 1996).

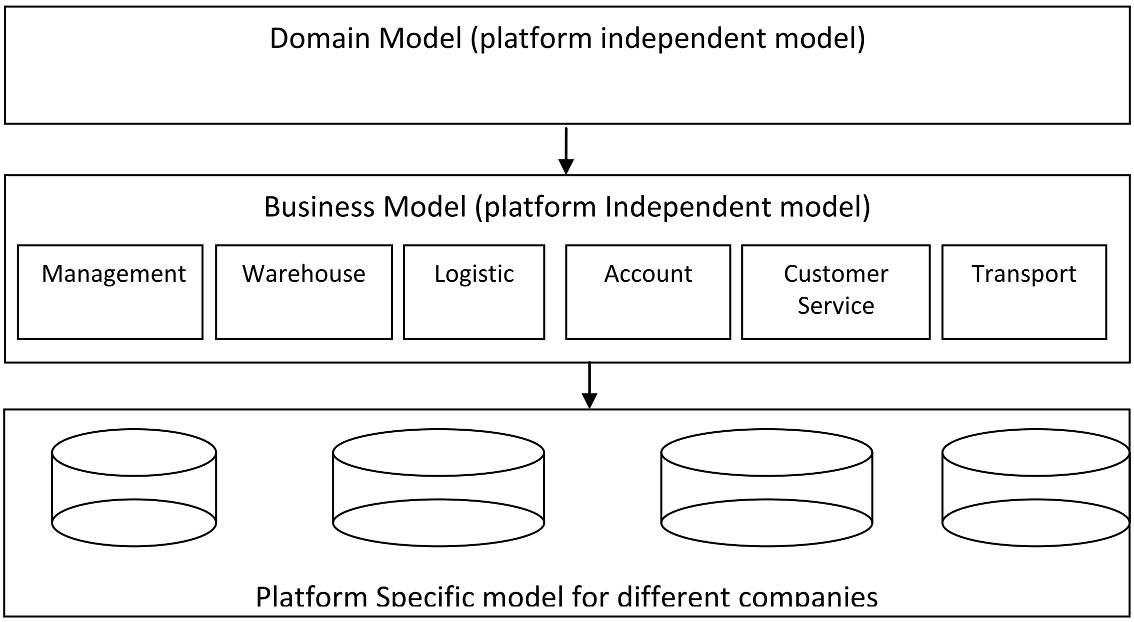


Figure 8-3: Platform Independent Model

8.4 COMPONENT SYNCHRONISATION OF SERVICE-ORIENTED FRAMEWORK

We propose some options regarding adaptation methods. The proposed synchronisation of similar components into one component is one step in a sequence of steps. For our purposes, we will be using Java files for the development of such applications. As we know, different methods can be used to arrive at a particular solution in Java. Therefore, when we want to concatenate two or more similar Java file with only a minute amount of different behaviour into one Java file, the proposed plan is to use intelligent software agents (ISA). We use Intelligent Software Agents (ISAs) because they include problem domains that require *human-like intelligence* operating *autonomously*. Consider the enterprise management department (please refer to Figure 8.4), where changes are to be implemented in the existing workflow. Generally, decisions of the management require marginal change, (assuming the range to be 0-50%); they usually require only a few changes to the already existing workflow. In such situations, we want to reuse the existing components of this workflow and change only those components that are different from the existing components.

In the framework layer, browsers interact with HTTP servers in their normal way taking advantage of any technologies that enhance this browser-to-web server link. For example, in the network layer, secure-socket layer communication protocols in Netscape and Microsoft browser/server products browsers communicate with HTTP servers, which communicate with the application server. The framework layer generates the web application at runtime, the communication layer provides the application's user interface and state management, and provides an environment to use and create reusable components (Anastassia, A. et al., 1998). An enterprise monitor repository helps by monitoring the front end as well as the back end of the system as shown in Figure 8.4 This framework helps to balance across one or more application server processes (also called instances) running on one or more machines. Once running, enterprise component service instances do not go away between user requests; they maintain themselves, their session's state for users, and their database connections. They are efficient, fast, and by definition, redundant. It is the job of the HTTP server adaptor to communicate with a given HTTP server and forward requests to one or more application ‘instances’ - an instance being a separate copy of a given application process. An enterprise services framework serving a few users may have only one instance. A large application may have tens or hundreds of instances running on one or more machines. If an application has more than one instance, the enterprise services framework controller is essentially acting as a load balancing agent. If an instance fails, it affects only that particular instance – all other instances and/or the site's web server is unaffected. The controller will forward requests via the network as easily as it will forward requests to applications running on the same box as the HTTP server. In fact, from a load-sharing perspective, it is ideal for the HTTP server and application servers to reside in separate boxes. Since applications are server-based, database access occurs behind the firewall. Browsers need never make direct connections to a database server. Services access controls the database connections so that they are highly secure (only accessible via actual application api), and conserved (that is, there is never more than one connection per instance regardless of the number of users supported - unless this is specifically something the developers desire). A Java foundation contains fundamental data structure, implementations and utilities used.

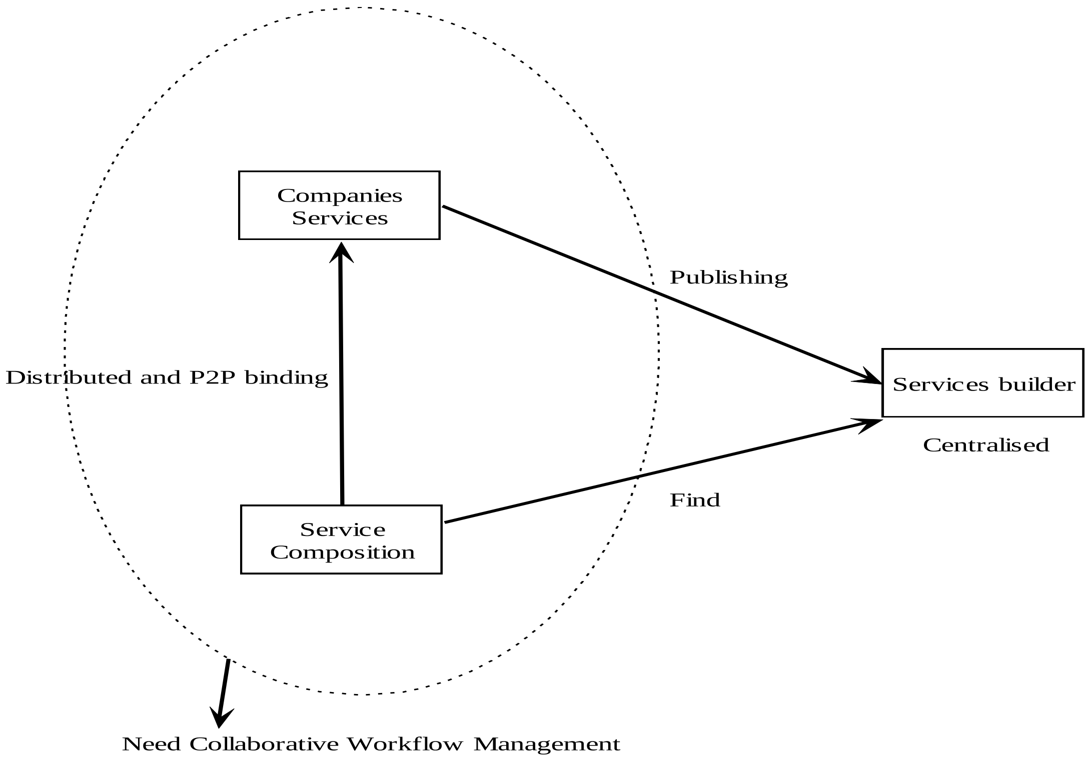


Figure 8-3: Enterprise Monitor Repository

8.5 SYNCHRONISATION MANAGEMENT

In the previous section, we proposed an adaptation method. For our purpose we will be using java files for the development of such applications. As we know there can be different methods to solve a particular solution in java. Therefore when we want to concatenate two or more similar java file with only a minute amount of different behaviour into one java file, the proposed plan is to use intelligent software agents (ISA).

A software agent (SA) is an artificial agent which operates in a software environment. *Software environments* include operating systems, computer applications, databases, networks, and virtual domains. An Intelligent Software Agent (ISA) likewise is a software agent that uses Artificial Intelligence (AI) in the pursuit of the goals of its clients. *Artificial Intelligence* is the imitation of human intelligence by mechanical means. Clients, then, can reduce the human workload by delegating to ISAs tasks that normally would require human-like intelligence. Many researchers who formerly referred to their work as AI are now actively engaged in ‘agent technology’. Thus, the word ‘agent’ by itself generally connotes ISAs in the terms of the present-day research community (Brandenburger, A. M. et al., 1996), (N.Y. Brennan, R., 2000). There are different types of ISA including mobile agents, distributed agents, multiple agents, collaborative agents and social agents. For our prototype, we use collaborative agents. Collaborative agents interact with each other to share information or barter for specialized services to affect a deliberate synergism. While each agent may uniquely speak the protocol of a particular operating environment, they generally share a common interface language which enables them to request specialized services from their brethren as required.

Some of the human-like intelligence capabilities that may be required of ISAs by the problem domain span some of the most difficult areas of research being pursued in Artificial Intelligence (AI) to date. Like Logical Inferencing and Deduction, Contextual Domain Knowledge, Pattern Recognition, Learning and Adaptively. Once the human-like intelligence capabilities are automated, however, an autonomous operation permits ISAs to process vast volumes of data which would be unmanageable by human agents. We use Intelligent Software Agents (ISAs) because they include problem domains that require human-like intelligence operating autonomously. Consider the enterprise management department (please refer to Figure 8.4), where changes are to be implemented in the existing workflow. Generally, decisions of the management require marginal change, (assuming the range to be 0-50%); hence, only a few changes are required to the already existing workflow. In such situations, we want to reuse the existing components of this workflow and change only those components that are different from the existing components.

The two-workflow processes, which have to be synchronized, should possess the same qualities, and this application should be developed using an object-oriented language Java, with low coupling and high cohesion. Suppose, for example, we call these two Java files ***class A*** and ***class B*** (Figure 8.5). We use ISA to find the similarities between these two files and process the information regarding similarities in methods of these two files.

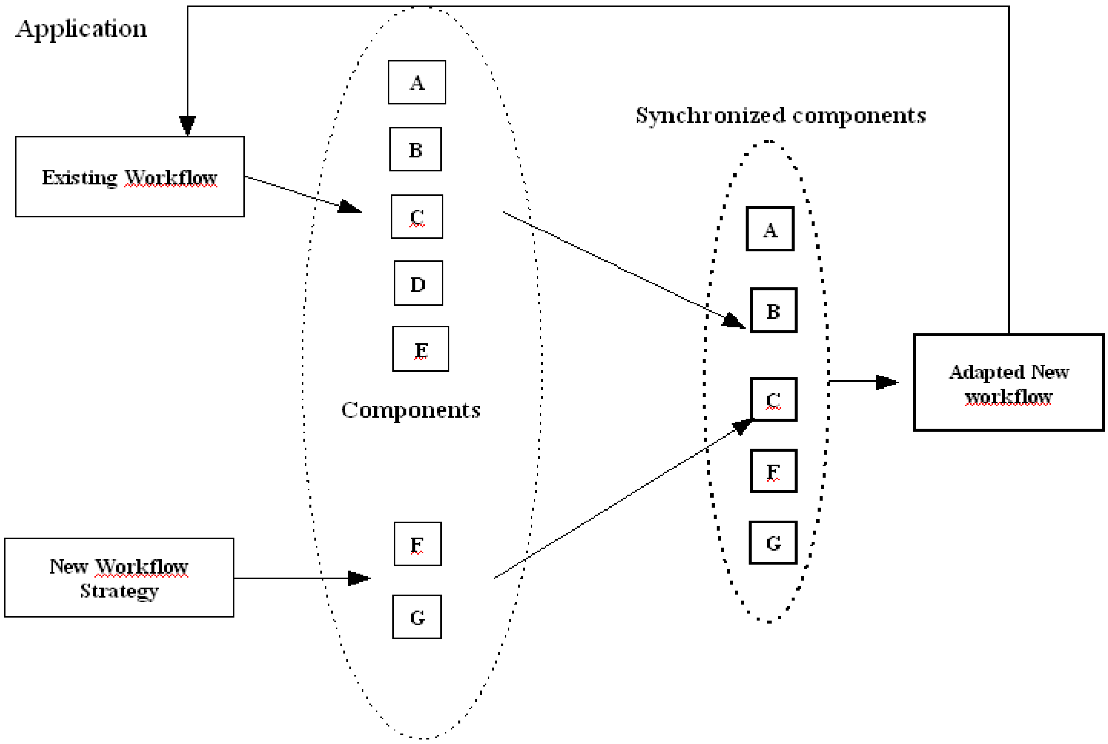


Figure 8-4: Synchronized Workflow Managemen

These ISA agents analyse the particular information to create the synchronized ***class C*** files by carefully copying components from class A or class B and pasting them into class C. Other ISA agents will analyse the information regarding the different functionalities of the classes. After retrieving different methods of information, these ISA agents will store them onto logs for future retrieval as and when required for the synchronisation to form class C. Here, the combination of two Java classes into one Java class incorporates the same components (objects) of the existing workflow and the changed components of the new workflow.

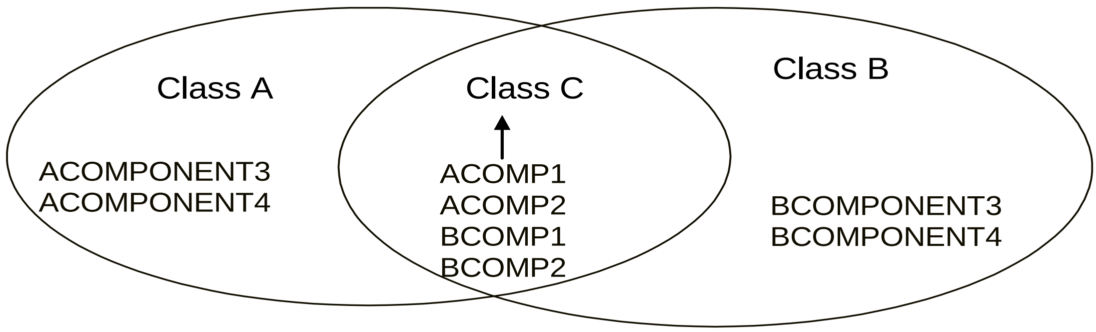


Figure 8-5: Classes Synchronisation

8.6 PROTOTYPE OF COMPONENT SYNCHRONISATION

We have built a prototype system based on the design presented in the previous sections. In this paper, an intelligent software agent-based inter-organisational workflow management system is proposed and implemented. We provided a Graphic User Interface so that the services provided by the consortium server can be seen and browsed, in the component service area; the web services provided by the corresponding consortium are displayed by logging in to maintain the security of the system. We provided a Graphic user interface for the monitor as depicted in Figure 8.7. This monitor is used to monitor the application and make changes, i.e. the workflow instances running and UML representations of configurations. The Bell warehouse management system contains a table where each column represents a dynamically reconfigured booking form. The execution screen shot can be seen in

Figure 8.8, showing the start-up of the Java monitor, used to also monitor the web services simultaneously. This area is used by the back-end user of this workflow to monitor the workflow execution, Backend Web Server Application Server and Database Servers.

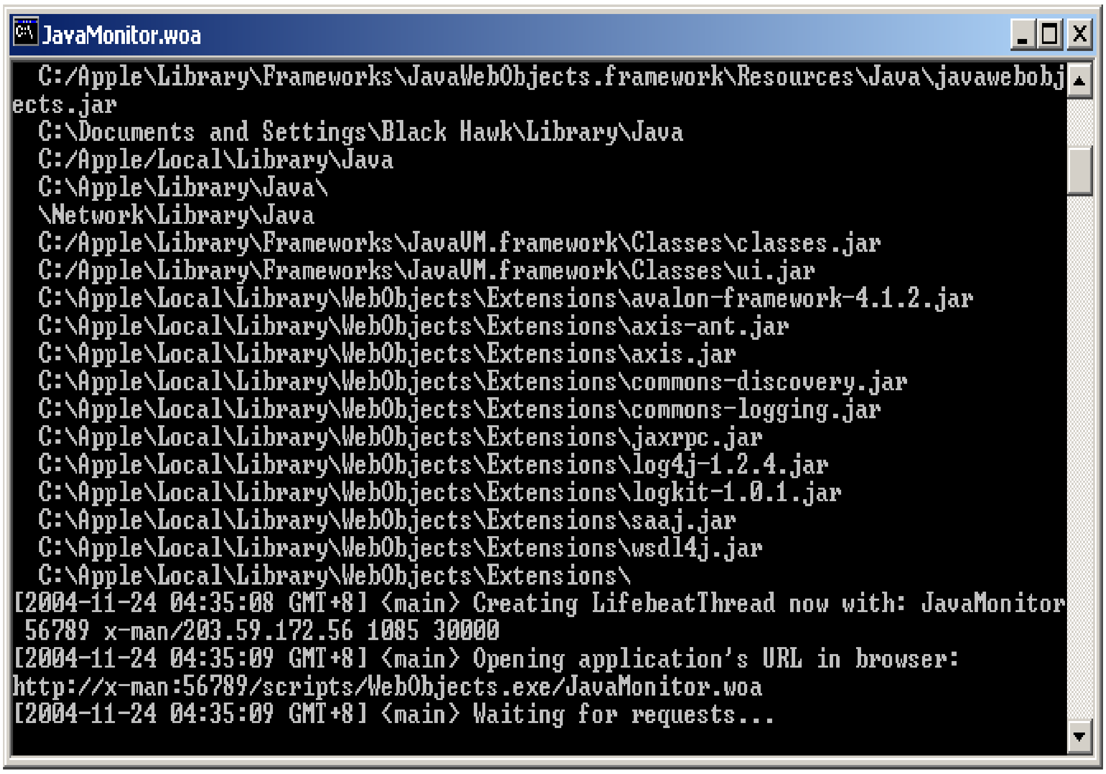


Figure 8-6: Workflow Logging

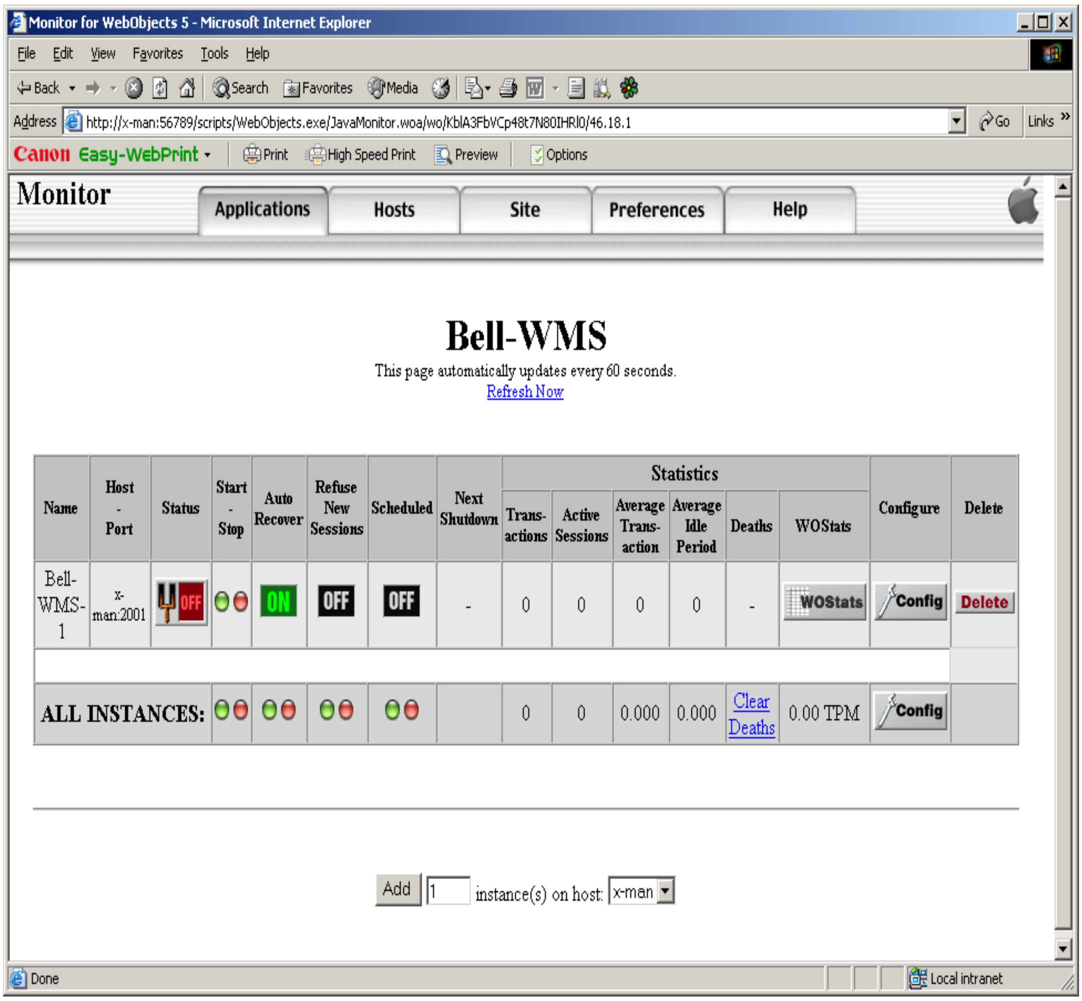


Figure 8-7: Prototype Bell Warehouse Management System

8.7 BACKEND COLLABORATIVE WORKFLOW

In this section, we present a service-oriented framework for collaborative logistics companies. The framework is divided in three sections: 1. Business web services layer; 2. Services communication layer; and 3. Process and transaction layer.

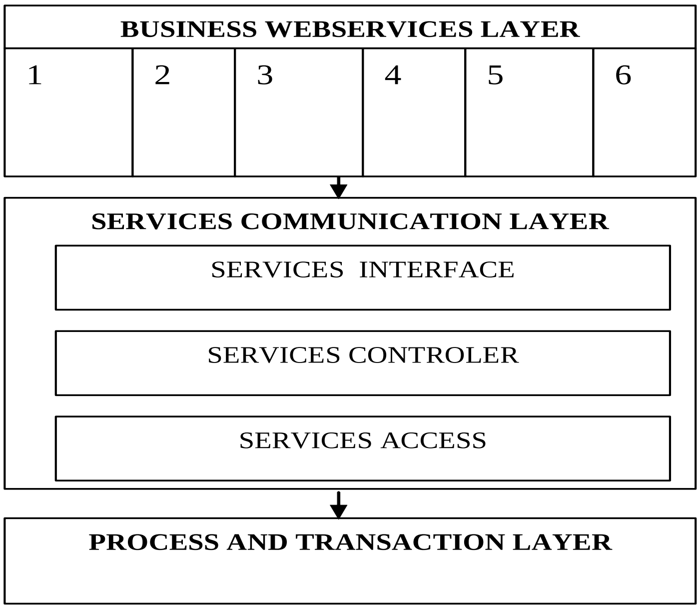


Figure 8-8: Enterprise Model Framework

In the Business web application layer, browsers interact with HTTP servers in their normal way, taking advantage of any technologies that enhance this browser-to-web server link. For example, secure-socket layer communication protocols in browsers communicate with HTTP servers, which communicate with the Application Server. The Business web services layer has an underlying process for generating web application indicated by 1-2-3-4-5-6 in Figure 8.9, at runtime, The Services communication layer provides the application's user interface, state management and creates an environment to use and create reusable components (Aldowaisan T.A. and Gaafar L.K.. 1999). The enterprise model framework shown in Figure 8.10 balances across one or more application server processes (also called instances) running on one or more machines. Once running, the enterprise service framework instances do not go away between user requests; they maintain themselves, their session's state for users, and their database connections. They are efficient, fast, and by definition, redundant. It's the job of the HTTP server adaptor to communicate with a given HTTP server and forward requests to one or more application 'instances' - an instance is a separate copy of a given application process. An enterprise services framework serving a few users may have only one instance. A large application may have tens or hundreds of instances running on one or more machines. If an application has more than one instance, the services controller is essentially acting as a load balancing agent. If an instance fails, it affects only that particular instance – all other instances and/or the site's web server are unaffected. The controller will forward requests over the network as easily as it will forward requests to applications running on the same box as the HTTP server. In fact, from a load-sharing perspective, it is ideal for the HTTP server and application servers to reside in separate boxes.

Since applications are server-based, database access occurs behind the firewall. Browsers need never make direct connections to a database server. Services access controls database connections so that they are highly secure (only accessible via actual application API), and conserved (that is, you never have more than one connection per instance regardless of the number of users supported - unless this is specifically something the developers desire). The process and transaction layer works on an underlying Java foundation containing fundamental data structure, implementations and utilities used.

8.8 WEB SERVICES LAYER AND COMMUNICATION LAYER

With reference to Figure 8.9, we see that each department has its own responsibility; however, they are connected to each other. In a collaborative context, communication may have to be coordinated not only within the organisations but also across organisations. Therefore, a consortium may require synchronized coordination of activities of inter- and intra-organisational departments. This conceptual model provides an architectural separation of business functionality from technology implementation. This separation allows designers to use business rules defined in a UML model to drive two distinct steps in implementing such systems.

Step1 Create platform-independent models in UML. The first model is a generic domain model, used to build a common understanding and vocabulary among warehouse logistics domain experts.

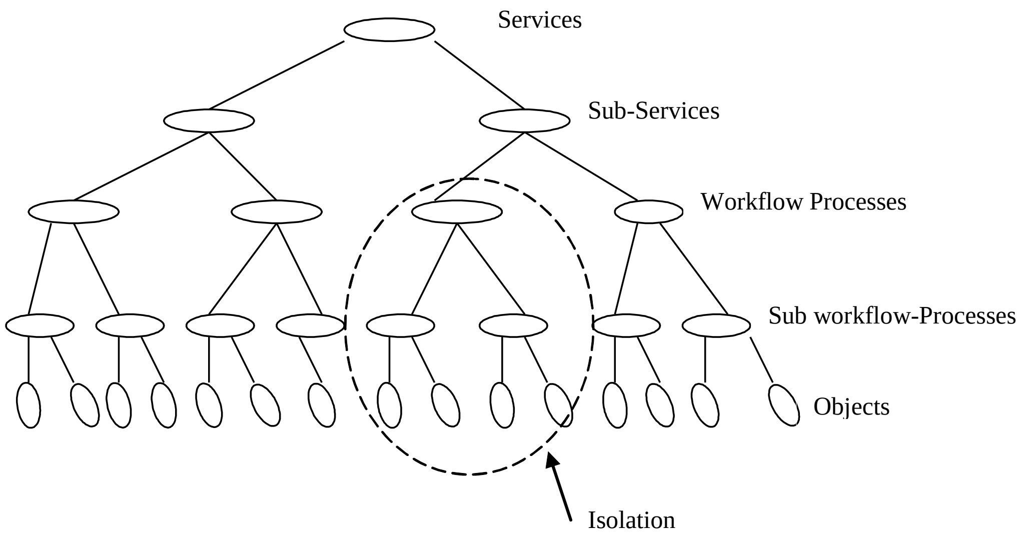
Step2 The domain model is then mapped into a representing warehouse logistics business. Each of the models includes a detailed set of UML Class Diagrams, Use Cases and associated Activity Diagrams describing the system (Brandenburger, A.

M. et al., 1996; Co-operation, Doubleday NY. Brennan, R., 2000). This logical architecture of the web services frameworks is a programming building block of the largest granularity. A web services framework is responsible for providing the application's user interface and state management. Since applications are server-based, database access occurs behind the firewall. Browsers need never make direct connections with a database server. Services access controls database connections so that they are highly secure (only accessible via actual application API), and conserved (that is, you never have more than one connection per instance regardless of the number of users supported - unless this is specifically something the developers desire). Designers can use business rules as defined in the previous section to define a UML model. Using this business model, we can create one or more subsystems to represent the logical functions of each of the enterprise systems. This business model contains both the details of the business logic and the mapping of the logic into the major subsystems. The business model forms the basis for managing all changes to the current systems. And the next step is System Integration using Conceptual Model of Platform Specific Models (PSM's), for each of the individual systems to form an enterprise system (Boley, H. 2006). These models were each derived from one or more subsystems in the business model. System construction consists of customizing each of the enterprise systems, and creating the business logic. Business logic that spans systems is constructed using components technology and is deployed in the application server also called web service brokers (please refer to Figure 8.8).

8.9 PROCESS AND TRANSACTION LAYER

This framework contains an underlying Java foundation consisting of fundamental data structure implementations and utilities used throughout the rest of the enterprise processes. Examples include arrays, dictionaries and formatting classes. These processes provide RDBMS independence for services persistence, object persistence transaction management, and services useful for web-based presentation and deployment. It also creates an environment to use and create reusable components. It facilitates the use of true business objects in a services-oriented framework and handles storing and restoring objects to a data store and usually in a relational database. Since the business processes and objects created don't care about the underlying database or how their values are presented in user interfaces, they may be re-used over and over in any number of different web applications and can be maintained by developers. A web services framework also provides a persistence layer to maintain information at all times.

As a single process can produce a huge workflow map, the *sub workflow layers* allow the workflow to be broken down into more manageable sections. This also allows modularisation of commonly-used functions – for example, bulk notification activities rather than having them repeated throughout the main map or even several workflows maps or systems. This also makes them easier to manage and maintain. A sub-workflow layer can be very useful to split your main process into its constituent elements – in a large process, this is likely to produce a quicker initiation and processing. However, in some cases, the overhead of moving from a 'parent' workflow into a 'child' sub-workflow can be a lot higher than the performance benefit of doing so; hence, we need to plan the workflow carefully.



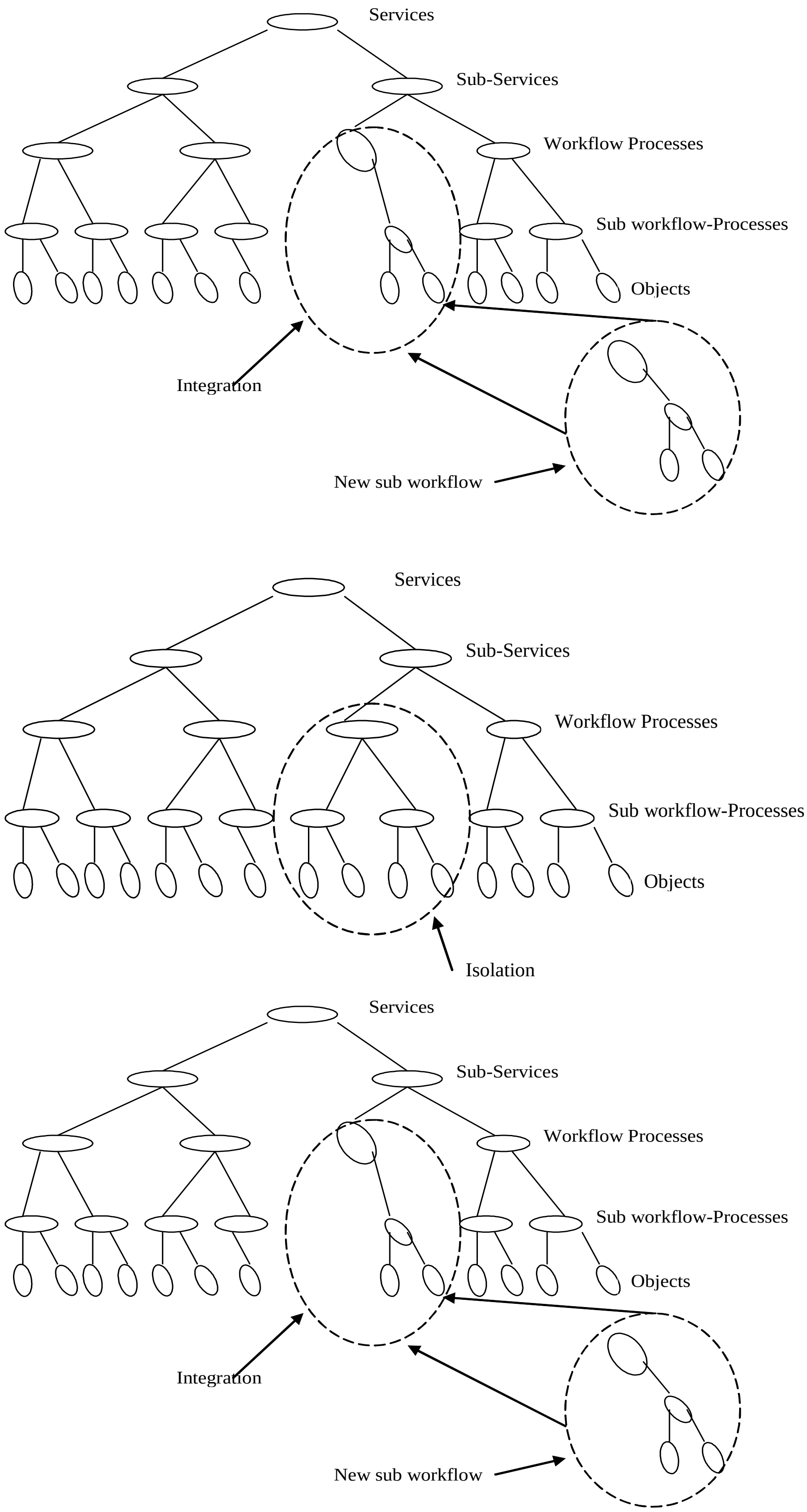


Figure 8-9: Isolation Replacement and Integration of New Workflow

This type of architecture will help to bring about main areas of change such as:

- Services Layer changes like criteria determining field colouration or visibility or edibility of a given field has changed, or a popup box is now required if some criteria is met.
- Data Changes / Mass Updates like Value Added Tax calculations need to be redone if VAT rate changes, customer name changes.
- Business Logic changes like Logistic criteria changes, routing requirements change.
- Patches / Bug Fixes that need to be applied to many active workflows.

The first case could be handled simply by adding one or more JavaScript functions and some CSS directly onto the affected forms. However, this may result in large-scale repetition of code throughout the workflow system which would be difficult to manage and any changes would mean loading in new versions of the affected views. One approach is to suspend, correct and restart each workflow in sequence, although for large numbers of workflows, this would be very time consuming. We have prototyped implementation using a services monitor.

8.10 IMPLEMENTATION FRAMEWORK

Large complex workflow processes are broken down into smaller workflows and *sub-workflow layers* to be able to better manage and maintain each section. Some process activities may be repeated throughout the main map or even several workflows maps or systems. This allows modularization of commonly-used functions and helps in easy management by the services monitor described in detail below. Data storage shown in Figure 7 aims to eliminate latency by allowing multiple applications to access a single physical data store directly. This architecture is suitable when applications and databases are located in the same data centre; this approach is more intrusive because we usually have to modify some applications to use a common schema. Reading data directly from a database is generally harmless, but writing data directly into an application's database risks corrupting the application's internal state. Although transactional integrity mechanisms protect the database from corruption through multiple concurrent updates, they cannot protect the database from the insertion of bad data. In most cases, only a subset of data-related constraints is implemented in the database itself . To avoid this, we include a services monitor which is a visual tool mapping software which is located between the applications and the data store/database.

8.11 USE OF SERVICES MONITOR TO IMPLEMENT DATABASE CHANGES

Services monitor allows us to identify the workflow processes and sub-workflow processes and objects stored in the data source, which need to be isolated and a new sub-workflow which has to be integrated it also helps to create, edit, or delete existing data store objects dynamically when connected to the data store. We can interact with the server data store using datastore diagrams incorporated in the service monitor. Datastore diagrams graphically represent the tables as in a normal database. These tables display the columns they contain, the relationships between the tables, and indexes and constraints attached to the tables. We can use data store diagrams to: view the tables in the database and their relationships, and perform complex operations to alter the physical structure of the database.

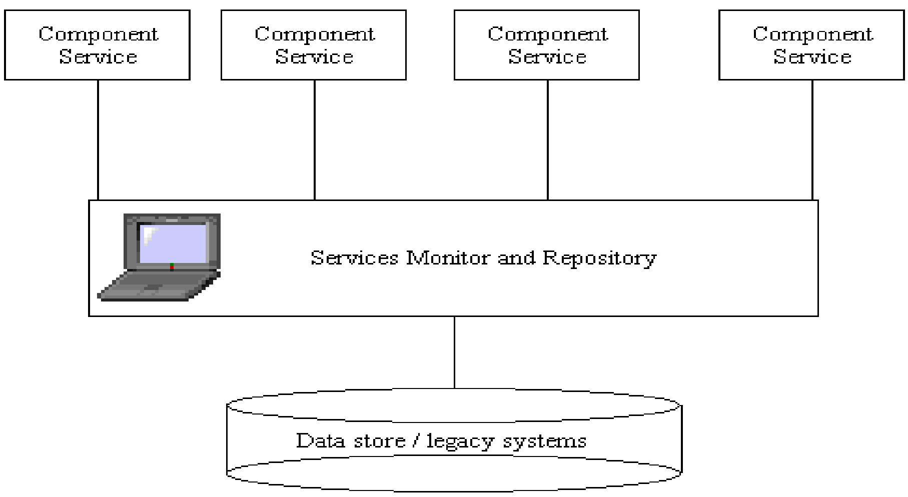


Figure 8-10: Implementation Framework

We can make changes freely in the datastore diagram without affecting the underlying datastore. When we modify a datastore object through a datastore diagram, the modifications made are not saved in the datastore until we save the table or the datastore diagram. Visualize the structure of your database tables and their relationships. Provide different visualizations of complex databases. Experiment with database changes without modifying the underlying database. Create new tables, indexes, relationships, and other constraints. Alter the structure of your database. Thus, we can experiment with 'what if' and various workflow scenarios and also check if these changes made to the workflow can be integrated into the existing workflow, using a datastore design without having to permanently affect its existing design or data. During editing, we can experiment with different object definitions to see if the proposed modification will affect the datastore. When we complete these modifications, we can either save our diagram/design or update the database to match the diagram, or we can discard it, leaving the underlying database unchanged.

Differentiating Database *Changes*

After the editing of the table in a datastore diagram, has been done, an asterisk (*) appears after the table name in the title bar to indicate that the table contains changes to the workflow that have not yet been saved in the database.

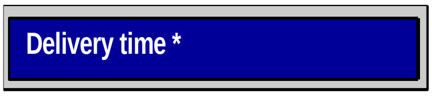


Figure 8-11: Implementation Change

This indicator appears as a result of a change made to the workflow objects in the datastore, represented as a column or index, in the table of the diagram/ design. When we add a modified table to another open diagram, the table appears there with its unsaved changes and an asterisk in its title bar. When the table or the diagram are saved, the asterisk disappears.

Identifying Updated Diagrams

Similarly, an asterisk (*) appears at the end of the diagram name in the title bar to indicate that the diagram contains workflow changes that have not yet been saved in the database.

Figure 8-12: Implementation Change

This indicator appears whenever a datastore object in the diagram has an unsaved change or the diagram/design layout changed since last saved. When the diagram is saved, the indicator disappears.

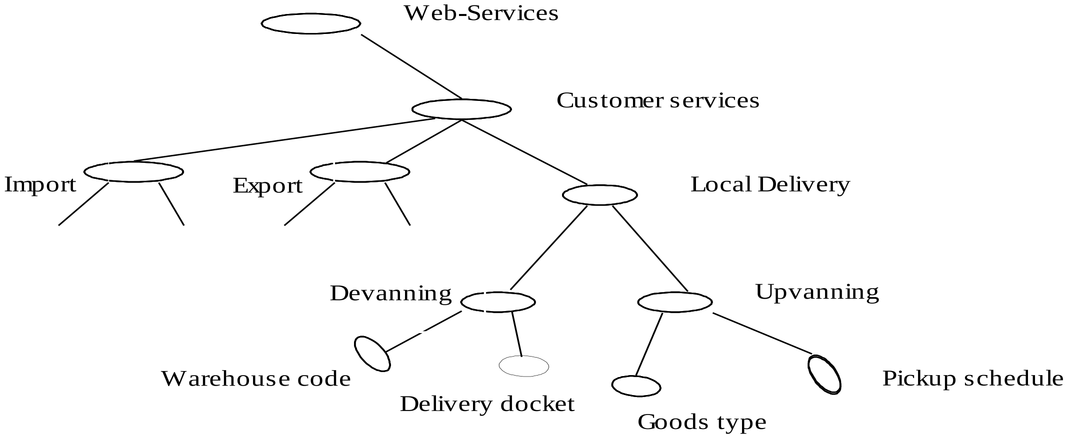


Figure 8-13: Example of Local Delivery Process

For example, a database diagram can be created for the customer services department that shows only tables that hold local delivery of goods information. We can create a diagram for this workflow part of the process that shows only those tables that are used in this specific workflow module. Here we can make a change to the devanning process to replace the warehouse code with a warehouse type code and delivery docket with delivery time. We can change the size, shape, and position of objects in the diagram without affecting their definitions in the database. When we save the datastore diagram, the layout of the diagram is preserved and any changes made to the object definitions in the diagram are also saved. So as to keep the whole consortium process running, we propose an exclusive locking mechanism; the locking level determines the size of the process that is locked. Performance and concurrency can also be affected by the locking level used. Exclusive locks are exclusive to the user until the changes are made without having to disturb the overall workflow. An exclusive lock on a record means that part of the process is denied access; therefore, that part of the workflow is isolated so that the required changes can be made only to that part of the process. One may choose some objects or even all of the workflow or sub-workflow tasks to be associated with implicit invocation. Figure 8.15 shows the implementation of customer entity in detail and Figure 8.16 shows the data store changes to the services monitor for the customer object of enterprise services.

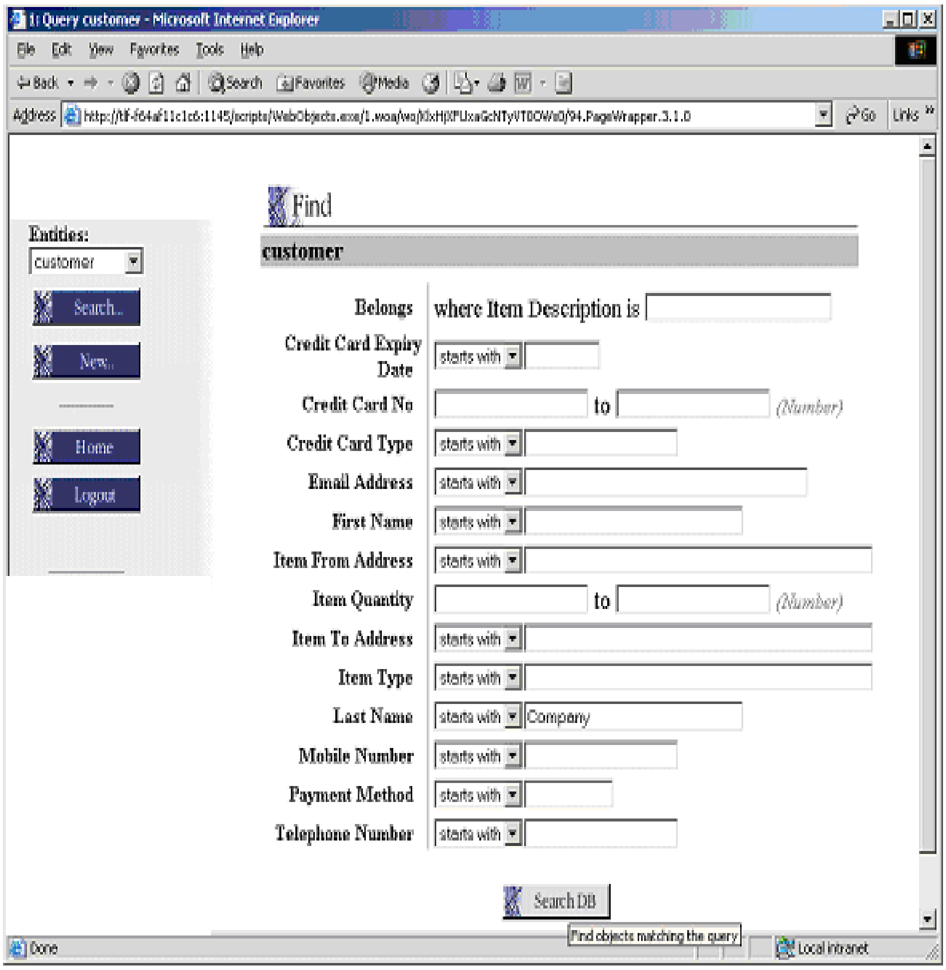


Figure 8-14: Example of Services

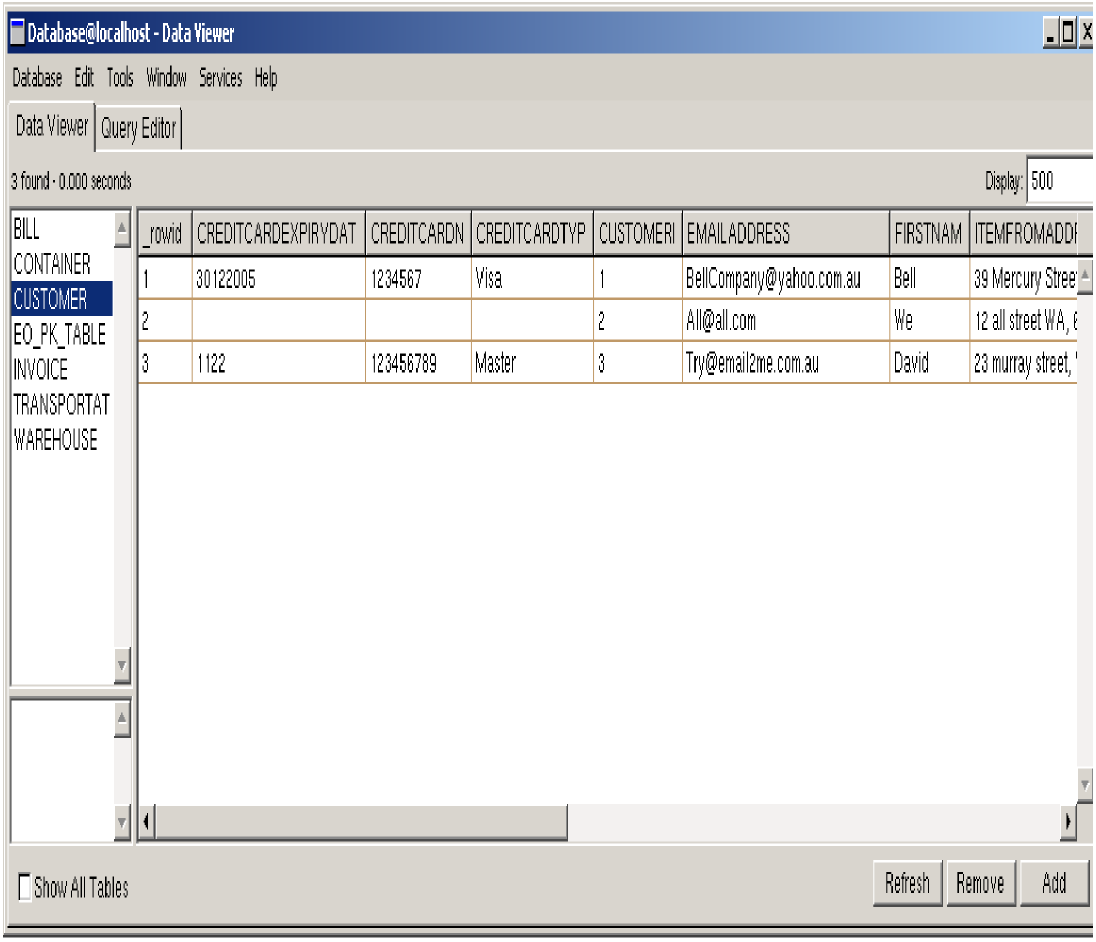


Figure 8-15: Example of Services Implementation and Component Integration

8.12 CHANGE MANAGEMENT

In a large collaborative organisation environment, daily operations are governed by a set of cooperative business processes in which intensive group-oriented human interactions are involved. A business process is an ordered (or coordinated) set of work activities. Workflow management can improve the efficiency of an organisation by streamlining and automating coordinated work activities throughout distributed environments.

Currently, most workflow management systems support workflow participants (or users) in performing work activities only in office environments. The growing popularity and maturity of mobile computing, however, has rapidly made it possible for many work activities to be computerized and automated outside the office. There are two implications for the automation of business processes using the emerging mobile computing technology. First, work activities that used to be performed within the office now can be done remotely, independently of a worker's location. Second, on-site work activities that had to be performed manually in the past can be computerized and automated with the advent of mobile computing. In this sense, mobile technology and solutions not only increase the flexibility of existing systems and applications, but also provide broader benefits for organisations through the re-design of business processes. To facilitate such improvement and re-design, it is compelling to provide support for a mobile workforce in workflow management systems.

8.13 CONCLUSION

In this chapter, we have discussed a service-oriented architecture for dynamic workflow systems. We have also discussed issues and frameworks service-oriented enterprises systems and have come up with a prototype for monitoring these various approaches for dynamic adaptation of the changes to the existing workflow. We proposed new frameworks for such systems by the process of isolation and integration and have come up with a prototype of a working synchronisation system. our future research will be to further test the implementation constraints of our prototype and propose changes as and when required.

Chapter 9 - Heterogeneous-Organisation Collaborative Workflow Modelling

9.1 INTRODUCTION

Heterogeneous organisations in a collaborative environment are those organisations that come together to form a community or a coalition for a short or longer term for a specific business or economic or social need. They are mutually and physically related, sharing a responsibility and a common set of principles between each other and each individual or an enterprise in this relationship cannot function or survive apart from one another. They are in an interdependent relationship where all parties are emotionally, economically, ecologically and morally self-reliant, while at the same time answerable to each other. Each party is an autonomous party.

Such inter-dependent relationship organisations present challenges in dealing with complexity. Because on one hand, they are partners without financial and economic arrangements; on the other hand, they are competitors in the same field or the same vertical industries.

In order to address heterogeneous organisation collaborative workflow improvement and management in productivities and efficiencies, we need to look at the underlying theory that could support such a complex cooperative environment. In this chapter, we first give a real-world example of a large-scale, complex, collaborative workflow environment, namely Australia Port Congestion Management. We then describe the key concepts that should be modelled in such collaborative workflows, and the challenges of modelling of these.

9.2 CASE STUDY: PORT OPERATION

As the volume of trade moving through Australia's ports is expected to triple during the next 20 years, "it is time for the way we plan and oversee our ports to change" "The resulting bottlenecks ... are hurting Australia's economic performance, causing lower productivity, slower growth and the loss of billions of dollars in export earnings" (AGE 7 Jan 20101, Ms Julia Gillard, Australian Prime Minister, Speech at WA Port). A joint effort between PATREC (Planning and Transport Research Centre), Port Authorities, Transport Forum and DEBII at Curtin Business School, has carried out extensive field studies and issue investigation at Fremantle port since mid-2010 and 30 plus port and road carrier operators were interviewed.

Several dimensions of the issues have been identified, and they are: The complexity of the problem is underpinned by the 162 registered largely are road carriers (2010 data) plus 70 on-port logistics operators (2010) that service the container movement (such as x-ray, custom, dangerous goods relocation etc.), of which 2% are large enterprises (namely stevedoring companies, the so-called monopolies) and 98% are SMEs. The SMEs were unanimously facing one core issue: the monopoly-based control on pick-up of containers at the stevedore companies which caused truck queuing and port congestion; this impacts on all SME port and road operators' economic planning, and especially affects SMEs' productivities and resulting financial losses.

In the last ten years, all operators including the stevedores have intended to cooperate and collaborate, and the core focus has been on the improvement of productivity, however, this has been a long-overdue dream yet to come true with no immediate strategy to move this forward to date.

The 'monopoly' based domination of the container movement has been due to the electronic-based Vehicle Booking Systems (VBS), which was developed and owned by the two stevedoring companies which is the source of the complaints among the SMEs and that cause the truck queuing issues resulting in economic damages to SMEs.

Other key issues raised are related to the infrastructure including ICT-based automation which is not included in this paper.

The difficulty of quantifying the extent of the economic damages for port and road operators creates immense vulnerability for SMEs. This has resulted in a lack of appreciation of SMEs' complaints, and slow actions to rectify the problems.

Figure 9-1: Large-scale Complex Collaborative Workflow Environment

9.2.1 The Freight Transport Challenges

The container movement is part of freight transport, which includes two primary parts: namely, import and export. The following two sections present a higher level pictorial representation of small-medium sea-port operations.

Import Container Movement Chain

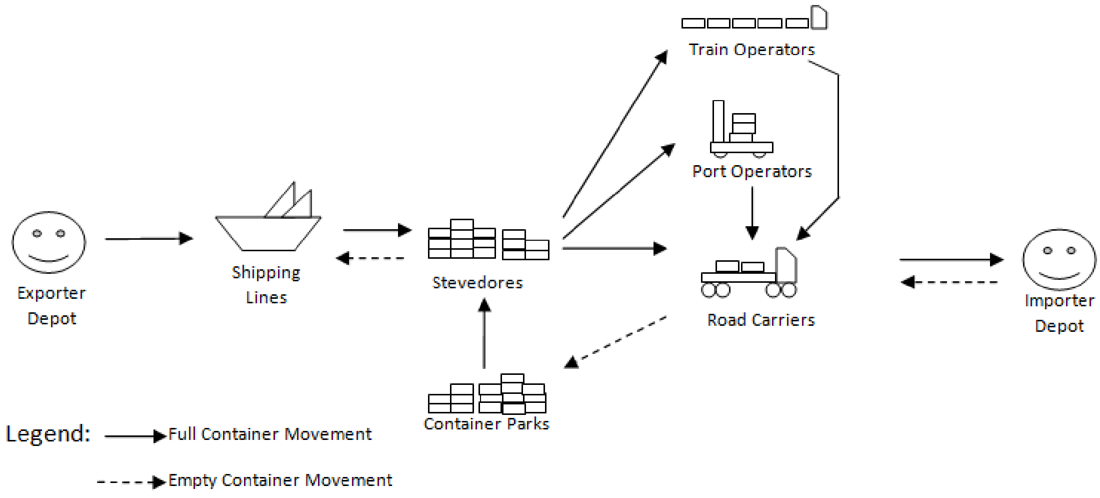


Figure 9-2: The Higher Level Pictorial Representation of Import Container Movement Chain

Export Container Movement Chain

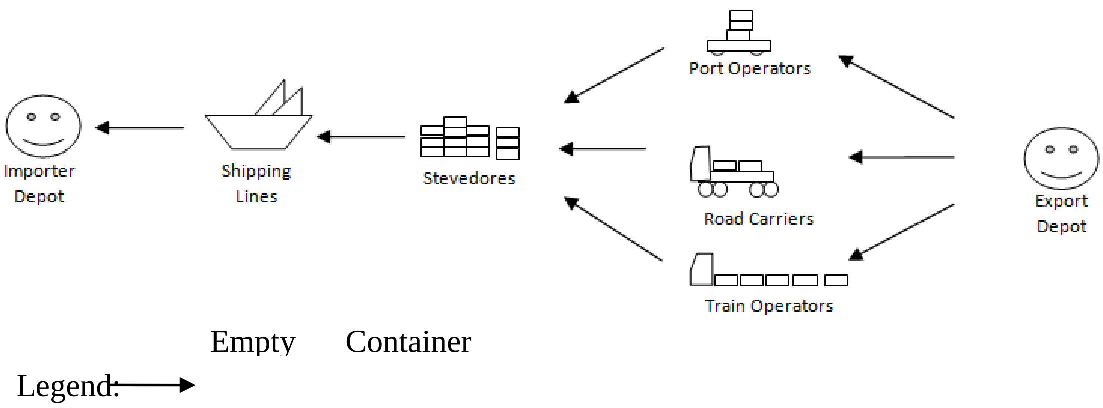


Figure 9-3: The higher level pictorial representation of Export Container Movement Chain

The container movement is controlled by the Electronic Vehicle Booking Systems with a tight time slot for pick-up of the containers.

Currently, there were eighty time slots per hour for each stevedore company, (one time slot assumed to move one container) we calculate the following scenarios:

1. If the port operates from 6am-10pm, 16 hrs/day, we can move 1280 (18*16) containers per day per stevedore; and with two stevedores, working 260 days per year (not 365 days per year, we exclude all holidays per year), we can move 660,000 containers per year.

2. If the port operates 24/7 as it says on its the website and only 260 days per year, over 900,000 containers could be moved per year, or

3. If stevedores can improve their efficiency by allowing 100 time slots per hour, for two stevedores, over $1 million containers could be moved per year and be able to cope with a growth of 20% in the next ten years as stated in the State and National Plan.

There has to be an exact amount of containers coming in to the port from the shipping lines, and an exact amount of containers moving out of the port and back again to the port, then to the shipping line. This balance has to be there, otherwise, more chaos would occur.

There are 2% large enterprises (stevedores) and they are very important enterprises. However, we have 98% of SMEs that shift an exact amount of containers in and out of the port. The SMEs pick up and drop off the containers that support the whole container movement, and their contribution to the economic development is significant.

The stevedores expressed that their waterfront berth is well capable of handling over 1 million container movements per year but due to the current chaos of SME operators, at present they can shift only 200,000 containers per year. This situation impacts greatly on the stevedoring companies' revenue despite the numerous complaints from SMEs.

One stevedoring company lost $1 million in Federal court fighting with SMEs in 2010 alone.

However, one of the small-medium logistics operators paid out $260,000 in fines or penalties to the stevedore companies in one year due to uncontrollable time-delays in picking up and dropping off containers. This is in addition to SMEs losing money because they are unable to function productively.

The acrimonious relationship between road carriers and stevedores has an immense negative effect on the whole economy.

In this paper, we use the bullwhip effect modelling techniques to simulate the container movement and bullwhip effect on small-medium road carriers and small-medium port-logistics operators. (In this paper, these two categories will collectively be called SME Road Carriers.)

9.2.2 **The Key Indicator**

The number of carriers and the number of containers being picked up are the key indicators for the productivity measure.

Stevedore's Indicator

Table 9-1 Productivity for Stevedores

Melbourne	Perth
245 carriers handle the container movement	162 carriers handle the container movement
740,000 containers movement a year	200,000 containers movement a year
The wharf front capacity is 1.5 million containers	The wharf front capacity is 1 million containers

Carriers' Indicator

80lots/ hr, 6am-10pm, 16 hrs/day, 1280 containers/stevedores

2 stevedores, working 260 days/yr (not 365days/yr), 660,000 containers/yr

if 24/7 as it says in the website, approx 900,000, or If 100 lots/hr, for 2 stevedore, 800,000, able to cope with growth of 20% in the next 10 years.

9.2.3 **Issues with Port Container Movement Management**

Currently, the container movement in the port is totally managed by a computerised software system known as "Vehicle Booking System" (VBS), which assigns times slots for road carriers to book their time to come and pick up the containers. The system was developed by an IT company and paid for by the two stevedoring companies, DP World and PATRICK. However, the system is designed to help these two companies, not the road carriers and the small-medium enterprises (SMEs). Numerous issues emerged that impede the SME performance and economics. Issues are summarised as follows:

- No transparency, some days start at 6am, some days start at 3pm, some days 80 slots, some days only a few slots available that need to be fought for; a third neutral party is required to monitor the situation

- Stevedoring companies state that this is not a VBS problem- there are too many carriers using VBS; transporters claim that the problems are due to the VBS which only looks after shipping lines, not carriers.

- No intelligent user support to book a continuing time slot, example such as pick-up containers A,B,C between time slots of 4,5,6, rather than computer gives the time slots of 4, and 8 and 12.

- No linkage with pre-gate operation

- No linkage to TCS

- No 24/7 and lack of consideration on carrier user interfaces

- Stevedore bookings are inflexible

- Secret deal about different time slots for each company

- Time slot delays

- Disjointed time slots distribution and difficult for pick up and/or drop off activities

9.2.4 **The Desired Functional Support for SMEs**

As indicated in the above, the Vehicle Booking System (VBS) is the key issue for SMEs logistics operators. In Fremantle port, there are 162 road carriers, and 70 port logistics operators who have to go to online and book their time slot for the picking up of the containers. Imagine over 230+ logistics operators all wanting the same time slots. If they are unable to secure any good time slots, they have to accept whatever time slots are available. This could mean that they have to pick up one container at 7 am and the other one at 7 pm. The VBS then executed a workflow control to control the movements of all vehicles and containers. Because the VBS is out of the control of the SMEs, and was not designed or developed by the SMEs, the workflow management occurs solely from the stevedoring companies' perspective and to meet their needs. Therefore, we consider the primary strategies should be to:

- Create a virtual VBS Hub
- Build intelligent recommender systems for continuing lot or bulk booking
- Introduce VBS-HUB, enable dual booking (drop-off, pick up); dual loading; dual way in and out
- Introduce a pre-gate system and linkage with TCS
- Eliminate truck queues
- Provide community visibility across parks, stevedores and carriers
- Provide valid empty container return information
- Introduce valid container release data from the shipping lines
- Introduce dual park and wharf booking with the same VBS interface for road carriers
- Provide comprehensive reports on all container movements and carrier performance
- Enhance VBS for Stevedores
- Identify Stevedores' requirements on interfaces, views and new/improved functionalities

- Identify Stevedores’ requirements on inter-operability, such as TCS, Pre-Gate operations, Wireless Track and Trace systems
- Identify Stevedores’ requirements on container yard optimization
- Identify Stevedores’ requirements on operation automation
- Identify Stevedores’ requirements on the target reports
- Identify Stevedores’ requirements on data intelligence and data mining
- Define detailed technical requirements that translate the Stevedores’ requirements into a software blueprint
- Work with one-stop-shop team on existing system
- Develop joint strategies to move VBS to a new level
- Support analysis, design, modelling and implementation of software components
- Support technology transfer with services computing
- Support system testing and deployment
- Enhance VBS for road carriers
- Identify road carriers’ requirements of existing one-stop-shop VBS including input, output, views, and intelligent logics
- Identify additional interfaces and views from carriers’ point of view
- Identify real-time reports required which provide some degree of transparent operation for container movement
- Identify the flow of Human System Interaction for carriers incorporating intelligent logics and system recommendations
- Determine detailed technical requirements that translate the road carriers’ requirement into software blueprint

- Work with one-stop-shop team
- Jointly propose software enhancement solution
- Design, model and document software components
- Support implementation of software enhancement, and add-on software components
- Support testing and customer training
- Ascertain general problems in Australian port
- Acknowledge that time and money are the concerns of all business

9.2.5 **Key Issue #1: Relationship between Road Carriers and Stevedores**

The relationship between the road carriers and stevedoring companies is considered to encompass other port operators and other road carriers. The fundamental cause appears to be the VBS, as they have no control over time and it costs them money:

1. No continuing appointment, pay extra labour costs
2. Fine or charges applied from the terminals
3. If they had a slot, however, there are external barriers such as them having to wait, pay labourers and cost run, they lose money
4. Cost may be passed on to customers which may result in loss of business
5. VBS is essentially owned by Stevedores and only helps Stevedores to manage/schedule the road carriers to pick up containers
6. The VBS provides little assistance to road carriers because it has limited functionalities and those functions consider only one side (stevedores), not the other (road carriers and other port logistics operators). To overcome this issue, we need to add functions or intelligence to VBS so that it will help other parties.

7. The VBS is the main system that seems predominantly to manage the entire operations for port businesses, that links and intercepts all parties. Due to its one-sideness, it is the source of the problems/conflict, as it helps only one party.

8.

9.2.6 **Key Issue #2: The Infrastructure Set-up in the Port**

The infrastructure set-up in the port has not helped road carriers. However, this is not a concern of the stevedores, but it is a concern to all the road carriers, including the other port operators. Issues of concern include:

1. Roads are too narrow for large trucks

2. Corner turn in the port is too narrow and sharp, difficult for road trains that have two or (in the future) three containers

3. Signs in port are bad with no indication where to go to locate a given place

4. No lunch or food places or shops for operators

5. No air-conditioned controlled cooling area

6. No pedestrian way/path for road drivers to walk around to shop or toilet

7. Only one toilet in one location, difficult for truck drivers to drive around to go to the toilet and then they often have to wait in a queue

8. Too many parties share the port, such as Ferry to Rottnest Island, bicycle route, port beach entry and parking, runners, dogs, other tourist/no business vehicles: a) the infrastructure was not intended to accommodate all parties who share the facility, b) large vehicle cannot stop when there is a bike rider suddenly across the road, especially on rainy days; c) affect business as those non-business activities are around and sometimes are too many, such as during the holiday period; d) environment is dangerous for all parties; e) no proper path built for non-business activities, creating health and safety issues for all port and non-port users.

9. Marinas are 500 m from heavy industrial area. This situation does not exist anywhere else in the world.

10. Private boats are sailing in and out, and it is impossible for large ships to manoeuvre around them

11. Union involvement creates strong opposition and stress between the two key parties, with both sides (Stevedores vs Road carriers) losing time and money as a result of ongoing conflict

12. Technology challenges

13. Currently, most road carriers do not have vehicle tagging, which can be linked to VBS, so pre-gate operation can take place. cost $2k for each truck. Marshalling area utilisation is poor; need RFID, tag and pre-gate operation.

14. VBS serve one-way need, not both parties; need intelligent modules and functions for carriers.

15. 'Far too many' organisations is the problem.

16. It is a highly ineffectual port, possibly the most inefficient in the country. In the following section, we copied the transcript of interviewee's complaints made by Stevedore DP world about the in-efficiency of the WA port operation.

"*DP world, the Stevedore indicated that "The number of carriers and the number of boxes picked up are the key indicator. WA port has 162 registered carriers that pick up 200,000 containers. Melbourne has 245 registered carriers that pick up 740,000 containers. At terminals, we do not have control the carriers registering their business, the key part of this is that we cannot stop them using our VBS. This is a big problems.*

DP World, the Stevedore said it is not VBS's problem, it is that we have too many carriers. He said it is better that you have 1 carrier come to pick up 200 containers rather than 200 carriers pick up 200 containers. With less road carriers, we can put containers and console them, put all of them together, and we know this carriers is going to pick all these. We can manage. With 100 carriers, we cannot console as we have to shift stack all the time, very efficient.

Similar to exporters, if we have one carrier, with 40 containers, we put the truck in, take the boxes straight into the stake/yard/terminal, without booking or sorting. However, if we have forty carriers, cannot console, and it is labour incentive to Stevedores.

We do not want them to lose business, but those carriers should not be allowed to come to the port, as they don't know how to run the business.

The working hours, 9 am – 5 pm, this is not driven by us, or port, or road carriers, or exporters. It is largely driven by Importers; they only work 9-5. In other ports, such as Melbourne Port, the boxes cannot sit on the port around the clock, they open 24 hours and around the clock, so the boxes are moved around very quickly.

As terminal operator, we understand the issue, we under the guide Asia Pacific .. duopoly, we have to be careful, we care "how we make changes" and "the change we make" by considering all. Two mechanisms to making the change: a) the 'price' and b) the 'time'. "How much for you to come to terminal" and "when you come to terminal."

***'R&D' (Receivable and Delivery)**, we will make change 6-2, and 2-10, we try to open 24 hours and 5 days, and take weekend off.*

Say the importers 'IKEA', 'Woolworth', 'Coles', they are not open till 8am. .. they do not pay their transport to work at night. However, our terminal operators work 24 hours, they have not got much thing to do. This is a hidden cost. These importers need to allow the container running at the night. They need to change their business model, it will be save for them too, and for us. Like in Eastern states, they are over night shift. Currently, no importer in WA allow/work containers over night. This is the problems. We can tell them how they can save money by allow container running at the night, but they don't do it.

We have day shift and night shift, and we work 24 hours with Vessel, but there is no 'R&D', because our importer are not working. Our labour is paid on fixed price and fix hour, we do not pay more if there is night 'R&D'. It will help everybody.

Container yards in WA port. It is supply chain, when some of them says they need to open longer hours, the chain along the line not doing it, it won't work (say not 'R&D' at the night); the issue is that if Road Operator operate 'R&D' at night, they do not need 'yard', they just put them in Terminal, and pick up at the same time. The small operators, only have 2-3 trucks, should work at night, they do not need big yard. They just come the terminal.

The key thing is the containers are not in and out of yard, if we have 3 times volume, our terminal space has no problems, we have enough Quay-lines (foreshore) in Global terms, and have enough space to triple the volume, and we should have no problems for the next 25 years. Otherwise, we have no problems. All we need is more Cranes, ICG, more operating equipment, more forklift. The Only problems are that the container cannot get out and in during the day, there is no 'R&D' and 'take ups' at night. Also, there is not enough infrastructures, only one way in and one way out".

Below, we present the complaints from the Road Carriers. In our study, we found that the transport industry and carriers are undervalued. Road carrier indicated that over the last 10 years, personnel from Stevedores at the container terminals in the port have not talked to Road carriers. They treat them with contempt. The number of containers arriving at the port terminal moved by truck is the same as the number of containers arriving by sea or by the Stevedores. Although, Stevedores do not pau Road carriers and vice versa, their relationship is very important, if one party stop working, the whole port operation will suffer, and affect economy not only for the logistics operators but the state economy. The conceptual representation of this complex relationship is presented below in Figure 9-4.

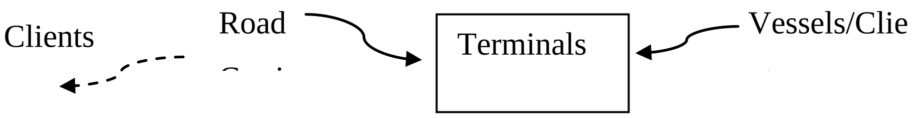


Figure 9-4: Large-scale Complex Collaborative Workflow Environment

An senior manager of Road Transport Association compliant about the poor management in WA port and stated that

VBS (Vehicle Booking System) were put in 1995 by Stevedores, Road carriers has no input to this system development.

VBS work for DP world and Stevedores serve their need. It seems Stevedores want to <u>make VBS hard to use</u> so get rid of Road carriers.

Some Road carriers don't have computers, cannot go on-line, or they use dial-up, or some are have the computers, but they cannot get VBS working on their computers. Some Road careers use dial up connections, it is too slow to make booking over the internet. Because the time slots for picking up the containers is filling up very quickly while computer network is too slow to response to the booking need. Most Road carreirs do not have maturity to run the e-business. The dial up user cannot get the slots. This is one of the major complaints, but Stevedore would say, it is not their faults. Road carriers should invest on their business by getting ADSL.

The Road carriers representative indicated that the key issue "there is not enough slot in a timeframe", Per hour say 1300 time - 1400 time slot (1-2pm time slot), there is 60 slots (1m per truck), the truck don’t turn up every minutes. 1300, when time opened, there are 30 trucks (Road carriers),they all come to that time slot. The Road carriers cannot control the time to arrive in port, and one cannot tell Road carrier that you cannot arrive early.

The empty park has no light, so they only operate daylight, and this is an issue. If we try to fit too many container, we physically cannot handle it. There is no data on it. It is not hard to find out.

There are also another system developed by the Stevedores, called **Terminal Control System** (**TCS**), the system is cannot sort the containers, therefore, it takes time to locate a container in the port, thus affecting productivity and performance.

‘TCS’ Terminal control systems- operate the container yard in the port it knows which ship it come from, where it is in the yard, it it does not do the sorting, such as support for first-in first-out. VBS - knows when the truck comes to pick up container A. At moment, these system don't talk to each other, they were not build to talk to each other at the time of development We hope the two systems can inter-operate, so that we know when the truck (Road carrier) is coming and move/locate the container to/on the top. It will be a significant improves the productivity and efficiency.

9.3 THE UNDERLYING ISSUES IN HETEROGENEOUS ORGANISATION COLLABORATIVE WORKFLOW

“The problems are very complex”, said Michael Pal on 16 July 2010. Several dimensions of the issues have been identified, and they are:

- The complexity of the problem is underpinned by the 162 registered business entities who operate on the port, who mainly are road carriers, of which 5% are large enterprises (namely two Stevedoring companies, the so-called Monopolies) and 95% are SMEs. The SMEs are unanimous in their complaint that they are unhappy with the monopoly-based control of the container movement and all port and road operators’ activities, which adversely affect SMEs' productivity, resulting in financial losses.
- While 100% of all port operators appear to have the intention to cooperate and collaborate, and are focussed on improving their productivity, saving money and resources, increasing efficiency thereby saving time and effort, there is no immediate strategy to move this forward.
- The ‘monopoly’-based domination of the port operation is through the VBS, which was developed and is owned by the two stevedoring companies; this is the source of the complaints by the majority of port operators.

Other key issues raised are related to the infrastructure which is not up to date; this includes roads and facilities, as well as lack of advanced technology support for automation.

We have conducted several presentations to cross evaluate our findings and research output and possible solutions both with several port operators and the Transport Association. These presentations have resulted in a better understanding of the port issues and enhance the proposed solutions. The underlying issues are:

- There is no financial arrangement, Stevedores and Road carriers one bring in and out containers from the sea, one pick-up full containers and return the empty containers through road networks. These two group of companies are operating on the same containers, but are not partners, and no service level agreement, they are all logistics operators, they all have their own customers.

- In WA port, there are total 160 Road carriers, and 70 on-port operators who work in the port every day.
- Only two large stevedoring companies which handle all in/out containers; 95% of operators are are SMEs
- Stevedores were seen as a super-power agent but unable to satisfy all the needs of SMEs
- The centrally-controlled port authority hierarchy is unable to fully control the complaint and poor productivity situation
- Issues have existed for more than twenty years and the situation is becoming increasingly out of control.

9.4 MODELLING OF COMPLEX HETEROGENEOUS ORGANISATION COLLABORATIVE WORKFLOW

As described in the above case study in this chapter, we note that the port is a highly complex collaborative work environment since no one small SME or large enterprise can operate independently. Yet, mutual disappointment and negativity has meant that collaboration has not been successful in terms of productivity and efficiency. This in turn has had a negative impact not only on the individual enterprises but also on the economy of the community and the country as a whole.

9.4.1 **Individuals in a Complex Environment**

A complex collaborative workflow requires complex solutions to issues and problems. Each enterprise, whether large or small, is part of a complex environment and system. If each one can operate effectively, this contributes to the efficient functioning of the entire complex environment. If each acknowledges that it is part of the environment, not a closed, independently-functioning entity, then they might appreciate that this is an opportunity for creating a bigger and better environment where individual enterprises can work not only for their own benefit, but also for that of everybody involved.

In the collaborative workflow literature,, many of the proposed solutions cannot be applied to a complex environment. Too many assumptions are made which are not relevant to each workflow situation; too many efforts fail and solutions on offer today may create more problems tomorrow. This is because complex problems do not lend themselves to easy solutions. In the last ten years, many studies have applied themselves to proposing solutions for the port operation. Yet the current situation suggests that none has worked; in fact, some solutions have exacerbated the problems. The whole centralized strategy developed by the local area researchers, consultants and domain expert or government have proven to be ineffectual and in fact might have created the opposite effect to that intended.

When the system is highly complex, the individual matters. We need a solution that is appropriate not only for the 'big' situation but that works on a small scale or for a cluster in a complex environment to improve the environment for operators and others. This does not mean that a system has to be bogged down by details; however, should not lose sight of the contribution made by each individual to ensure that the environment and all entities operating within it, work. If the concerted efforts of individuals are recognised, then a collective effort will contribute to the environment, the community and the society. The key here is to recognize that each individual (whether it be an SME or large enterprise) can contribute to the improvement of the environment and helping others. Following this principle, we developed a framework for modelling heterogeneous organisation collaborative workflow.

9.4.2 **Distributed Self-Organisation vs. Hierarchical Centralization**

Generally, there is no one way to model the complex collaborative workflow and through the literature study, we see that there are no best practices that apply to all type of collaborative workflow. Therefore, modelling has to consider the structure and type of the workflow in a particular complex environment. Therefore, we need to:

- Model the collective behaviour
- Model the perspectives of the complex systems from different observations
- Model the evolutionary process that formed the complexity

Model The modelling of a complex collaborative workflow transforms the management from small-scale enterprise or enterprises management to large-scale complex environment management. The traditional hierarchical command and control management is inadequate in today's networked economy as the world has to shift to more distributed, self-organisation and networked environment. As there is no one 'best practice', the goal is to develop a collaborative workflow model that suits the intended function, and build a system of policies and procedures that are appropriate for the environment that provide a key to renewed organisational structure of the environment and information flows. Therefore, we have to develop a modelling approach for a complex collaborative workflow based upon an understanding of how complex systems emerge in nature. We model the emergence and interdependence by modelling the relationships between parts of a system and examining how these relationships lead to collective system behaviour. In our society, individuals generally do no act separately, but are constantly interacting with and relating to each other. We model how patterns can arise from interactions naturally without deliberately putting parts in place and forming a pattern. The pattern of interaction relates to the system structure and environmental set-up. We model the functions the system performs, and the set of actions that are related to the function; we need to see why some parts are able to handle complex tasks, and some parts cannot. There is strong support for Bar-Yam's (2004) view that a traditional hierarchical centralized management is no longer capable of managing highly complex tasks environment. Therefore, we have to model the distributed networked environment for the next generation of large-scale complex systems or environment management. The modelling goal here is to look at the parts in the whole or the agents in a network and how they can get together, work together and how they can be more efficient and effective over time and how that contributes to the resolution of major problems in a complex environment.

9.4.3 **Modelling Parts, Relationships and the Wholes**

Our world is made up of parts, and parts are made up of smaller components or parts. When we want to model the 'whole', we start by modelling the 'parts', the 'components' and 'smaller components', 'smaller and smaller component parts', until progressively, we lose the 'whole' picture. What is missing here is the 'relationship'. We therefore need to model the relationship between and amongst the parts. It is much difficult than modelling a part of an object. But it is very important to help us in answering questions or solving problems. It is the relationship between the parts that gives rise to the collective behaviours of a system. Complexity and scale are balanced against each other. Cooperation and competition always work together and it is the essential part of evolution that forms a collective cooperative behaviour in the entire collaborative environment. It is important to model 'wholes' so that we do not run the risks of missing the larger picture.

9.4.4 Emergence in the Modelling

An old saying that is pertinent here is: "you can't see the forest for the trees". a forest is a large, complex system. However, trees, plants, animals and human beings inside the forest are components; you can see them when you zoom in. Each has its own behaviour. A forest is made up of the behaviours of flora and fauna. Forest behaviours are collective. They are what the parts do together. By zooming in and out, we see the emergence of patterns of 'whole' and 'parts'.

Emergence derives from modelling different perspectives of the same thing at the same time, and modelling how they are related to each other. To be able to model the entire collaborative workflow, we have to model the details of parts of the workflow. The challenge is how to determine how much detail needs to be modelled, and how much can be omitted in order to arrive at a model that is appreciated and understood and can be implemented and managed to the maximum efficiency.

9.4.5 Interdependence in the Modelling

'Interdependence' is distinguished from the concepts of dependence, independence, partial dependence and partial independence. Interdependence here is defined as a dynamic of agents or enterprises that are mutually and physically related, sharing a responsibility and a common set of principles with each other. It also implies that each agent or an enterprise of a relationship cannot function or survive apart from the other entities. In an interdependent relationship, all parties are emotionally, economically, ecologically and morally self-reliant, while at the same time answerable to each other. Each party can be autonomous.

'Parts' are interdependent. Often a decision on a workflow change pushes 'part' of the complex environment 'here', resulting in big problems 'over there'. Regarding the port issue described in this chapter, a long-standing problem is that of Port congestion which affects all parties. Despite the fact that all parties have made joint decisions over the last ten years, the problem of port congestion persists, producing a great deal of angst for all operators, local government and authorities.

Therefore, modelling the interdependences in the collaborative workflow is to model the how ‘parts’ affect each other. If one takes a part of the system away, both the part itself as well as the entire environment will be affected. We need to model the small effect, large effect, many effects and a few effects and determine the strength of the dependencies between the parts. This is an important step in understanding and modelling complex environments and complex collaborative workflows.

9.4.6 **Neural Networks Models Mapped to Collaborative Behaviour Models**

A pattern of group or individual interaction in a community or a collaborative environment is similar to patterns in the brain, which arise from interactions between neurons, the cells that comprise much of the brain. The society, or the community or a collaborative environment is just the same; patterns of collective behaviour are based upon interaction between people or individuals or organisations.

Neurons connect nearby neighbours as well as the neurons that are far way. It is a complex connected network. Neurons have diverse forms and behaviours; they affect each other through connections and often influence each other through their neighbouring neurons. An active neuron is likely to fire up near neighbouring neurons to be also active, it maps to social influences and the firing patterns changes over time, due to neurons acting on each other.

The patter of firing of neurons is also influenced by the external world through the activity of sensory neurons, like sight, hearing, touch, taste and smell. It is similar to the world around us and our human actions. A person’s behaviour is represented by the patterns of the neurons.

The network complexity increases with the number of connections in the network. If all the neurons are connected to each other, the complexity increases as does the capacity and capability. In our real-world collaborative environment, there is a trade-off between independence and interdependence. When the parts of a system are independent, those parts are free to respond to independent demands of the environment. However, when the demands on one part of a system are linked to the demands of the other part, those parts will perform well only if they are connected to each other.

This is why we need a collaborative workflow solution that needs to be organised in certain ways in order to be effective for specific local tasks as well as global tasks. Independence between certain groups is important because it frees each of them to respond to the independent demands of the environment. Only when the demand on one group is linked to the demands on the other group, should they be connected to each other. We therefore can define whether parts are to be connected to each other and not otherwise, so that we can achieve the collective collaborative behaviour we have targeted.

9.5 COMPLEXITY AND SCALE IN HETEROGENEOUS ORGANISATION COLLABORATIVE WORKFLOW

In the Port issues described in this chapter, every organisation including the government seems to be complaining about how complex the operation is becoming, and how bad the situation is around them and that they cannot functioning properly to achieve desired economic outcomes, etc. This naturally leads to the observation that our social and economic systems are becoming more complex, and everything in the world is becoming more and more interdependent. If there is a change in one part of the world, then this affects the rest of the world and the more interdependent we become the more complexity there is around us and the scale of the complexity increases.

Traditional management of complexity is through hierarchical management. It defined a communication channel, and that communication is up or down through the hierarchy, from the bottom up; the communications filters the information that is needed for the bosses, while the communication from top down provides details that are needed for the job to be done.

There is a trade-off between complexity and scale. Sometimes the controlled hierarchy is designed to achieve coherent motion through a group acting uniformly, and sometimes this can have a large-scale impact on a special environment; an example is the military hierarchy.

There are different types of hierarchy management of complexity in a manufacturing environment; hierarchy enables the Chief Executive Officer (CEO) to control large-scale operations. The CEO needs to know something about what individuals are doing, however, s/he does not need to know everything about what they are doing or all the details about what each person does every minute of every day. A CEO needs to know or control matters that affect a large portion of the organisation. There is a limit to the complexity. If the large-scale behaviours are communicated through the CEO, the large-scale behaviours cannot be more complex than the CEO. The complexity is large, and can be as large as a CEO, but it is limited, it is a finite amount of complexity that depends on the CEO's capacity. This demonstrates that hierarchy limits the complexity and scale. Therefore, collaborative workflow cannot be arranged just as a hierarchy or in a centrally-controlled manner. We need a workflow management that can deal with the complexity and at the same time be able to scale up.

Today's world is not purely hierarchical. There are combinations and hybrids of hierarchies and networks. There are many lateral connections and vertical connections. This mixed structural management produces complexity and scale for the benefit of the organisation or the community.

Being complex is the only way to succeed in a complex environment. A complex environment is the one that demands the right choice in order to succeed, because there are many possibilities that are wrong, and only a few that are right, and we have to be able to choose the right ones in order to succeed. This requires a high complexity, because the number of right choices is small and there are many possible wrong choices that exist for each right choice. More complex organisms have more options, which in turn enable them to make more right choices.

Complexity is very important for survival or success; scale also matters. Large-scale challenges or operations should be met with large-scale solutions or sophisticated environments. The rule of thumb is that the complexity of the organism has to match the complexity of the environment at all levels in order to increase the likelihood of survival or success.

In the complex collaborative workflow, we see both complexity and scale. It is important to model both concepts in order to make the right choice for the defining of the parts or agents and relationship between the parts or agent for the entire workflow to be successful.

9.6 EVOLUTION, COMPETITION AND COOPERATION

Collaborative workflow is the dynamic formation of a community with an inter-dependent partnership to carry out complex tasks, resulting in benefits for the individuals and the community. The complexity arises from the inter-relationships and drives the collaboration forward for productivity, efficiency and profits. However, this collaboration is sensitive due to the partners or agents in the collaborative environment also being competitors in the same field, namely, logistics and transportation. Is it possible for them to collaborate? Why, over the last over ten years, efforts and initiatives to reform port operations have failed totally. In order to answer how the collaborative environment can achieve maximum outcomes, we need to examine how competition and cooperation could work together.

Evolution involves looking at the pattern formation, determining the cause of the patterns and understanding the reason for that particular form or combination. The theory of evolution provides the answer to how patterns can be formed and combined and generate a new complex organism or entity through changes that occur over and over again or over a long time or over many years or many generations.

Biological evolution refers to the populations of organisms being transformed over time, and change occurring only between the generations, and not individuals. Evolution occurs by natural selection, and as indicated by Darwin's theory, evolution occurs through competition. However, many researchers today believe that understanding the 'competition' is not enough to describe the evolution process. On the other hand, many researchers do not acknowledge that evolution is a process involving competition and cooperation, because they believe that it is impossible for cooperation and competition to co-exist.

In the collaborative environment, the first step is to determine the individual's willingness to cooperate, so that we can distinguish cooperative 'team players' from selfish non-team players. This can be established through impartial peer reviews, track record and references.

In team sports, team cooperation is essential if the team is to deliver maximum, competitive performance. The competition between the team motivates cooperation between players. The competition at the team level improves the cooperation between players. Over time, winners by natural selection will remain and poorer performing members or teams will be eliminated. Teams that do well also rely on continuing improvement, learning by copying, or emulating the most successful competitors.

In the business environment, collaborative workflow is not analogous to do this constructive team sport relationship and context. The 'team member' in a collaborative workflow is a complex organisation, and it is a competitor. When we put the competitors together, and we ask them to collaborate, it is a wasted effort. What will motivate them? With whom will they compete? Who are their adversaries? It is true that the competition creates more collaboration within a team, and this collaboration enables a team to compete effectively. However, this is like comparing a tree with a forest, where the collaborative workflow for the heterogeneous organisation is like a forest, and we need to work on a much bigger scale from a broader perspective and higher level than for team sports.

It is acknowledged that competition and cooperation coexist and co-act together at all times and are an inevitable element in our environment. However, they work when they are at different levels; for example, in team sports, cooperation between the players, and competition between the team the collaboration work if they are at different levels.

Competition at the same level does not work. This is particularly evident in team sports. If two key players compete with each other for attention instead of cooperating as team members, the team will not perform well. On the other hand, cooperation can make a team unbeatable. Therefore, the heterogeneous organisation collaboration seems more prone to failure than success, as the players are all competitors, and they are not 'team players'.

The port management issue is the "the team against team competition issue". The collaboration between teams is what makes them succeed. Team against team competition is a business; the collaboration is intended to maximize the profits for each individual team. They need to cooperate with each other to decide the rules and play or perform according to those rules. The rules must be agreed upon and adhered to by all parties.

In the complex business environment, completion and cooperation can only be appreciated through multi-level perspectives. Competition and cooperation work well when they occur at different levels, and produce conflict if they occur at the same level. There are very few work down at the scientific level about evolution through competition and cooperation at different levels, and there are no research done in the area of the competition and cooperation at the same level. The difficulties in this research are the visualization of many levels of different heterogeneous organisations on a large-scale in a complex environment and at the same level, such as in Port operation situation, over 200 operators are all Logistics Operators (vertical industry), and they are at the same level, unlike supply-chain (horizontal industry), . Specifically, the difficulties are:

- defining a scheme for the past and future inter-dependent and inter-related relationships (a simple example, for a person, history, past, levels in the family, neighbourhood, community, society, social context, country …)
- defining a system structure that includes a competition, rewards, and a presentation of success.
- identifying the mutual goals and agreed cooperative activities
- preventing destructive competition from occurring and establishing the rules to prevent mutual injury

Hence, multi-level perspective on evolution, competition and cooperation is going to be extremely useful in the study of biological organisms and ecosystems.

9.7 DISTRIBUTING COMPLEXITY

Each organisation or individual has a certain level of complexity or sophistication. A workflow task can become difficult if the operations of an organisation or individual are not sophisticated enough to handle complex tasks. Therefore, the management of workflow needs to be considered more closely so that complex tasks can be distributed among many organisation and many individuals. It is similar to distributing the effort required to complete a task.

It is not enough to distribute tasks; management must also ensure that tasks are completed successfully. The management also needs to ensure that a balance exists so that no one entity is overloaded or has too much to carry, since this carries the risk that one failure will lead to a cascade of failure throughout the rest of the environment.

Distributing the responsibility for a complex task is also challenging; generally, the task is distributed, but not managed. Over a period of time, due to lack of communication, no-one knows how to coordinate the joint effort of multiple organisations or individuals or it might be that no one cares how the total joint effort can or should achieve on a large-scale. This deemed failure, the inability to recognize the complex and how it affects themselves or others or the entire community, is a central problem in managing complexity today.

However, while technology can provide some automated solutions, computers today still cannot replace human beings or the entire organisation and tasks or jobs are becoming more and more complex than human beings, or computers. Technology alone cannot be relied upon to solve the problem.

The workflow management systems provide some solutions such as coordinating tasks in time intervals, analyzing the flows of information and presenting the way the tasks are distributed throughout the system.

Today, 0rganisations that operate in a collaborative environment have to accept that evolution is created through changes and changes are the result of competition and cooperation. Therefore, on-going innovation will help to position and re-position the organisation or the community in the forefront of a complex environment.

9.8 CONCLUSION

In this chapter, a real-world case was presented of a heterogeneous organisation's collaborative environment, namely, the Port Operation. We introduced several key concepts regarding this type of collaborative workflow, namely, complexity, scale, inter-dependent relationship, evolution, competition and cooperation. We explained the significance of these concepts in the modelling of collaborative workflow and the related challenges. These key concepts are part of a heterogeneous collaboration workflow and much research needs to be done to advance this area of research.

Chapter 10 - System Dynamics for Heterogeneous Organisation Collaborative Workflow Modelling and Management

10.1 INTRODUCTION

In this chapter, we have given a very complex case study namely Port Congestion Management in an Australian Port, specifically, the data sample was from Western Australia Port. We also introduced a set of concepts into a large-scale collaborative workflow modelling and complex environments. We exposed the challenges in modelling these concepts. In this chapter, we examine several scientific approaches to modelling a large-scale complex collaborative workflow including swarm intelligence, chaos, bullwhip effect etc. The chapter concludes with a description of the preliminary experimental study and results obtained by utilising those scientific models. We believe this is the first time that these scientific approaches have been used to model large-scale collaborative workflow.

10.2 PARTICLE SWARM INTELLIGENCE

10.2.1 Swarm Intelligence

The notion of swarm intelligence is inspired by ecological principles in nature, where species enter an environment and in order to conserve it for their own benefit and profit, they need to interact, communicate and coordinate for their survival and sustainability. They are distributed, autonomous and self-organised, and use collective intelligence to evolve, to generate and to survive.

Figure 10-1: Distributed Intelligent Paradigm; images copied from DEBII Research Handbook 2007 and 2009

Swarm Intelligence has emerged in recent years as a distributed intelligent paradigm for studying the optimization problems related to the activities of large-scale objects. It is inspired by the study of biological and ecological systems and behaviours such as those of flocks of birds, shoals of coral fish and swarms of bees and ants.

10.2.2 Particle Swarm Optimization

Particle Swarm Intelligence and optimization refers to a number of simple entities being placed in the search space of some problem or function, and each particle evaluates the objective function at its current location. Populations of particles are organised according to some sort of communication structure or topology; it could be thought of as a social network. Each particle determines its movement through the search space by combing some aspect of the history of its own current and best locations or best fitness with those of one or more members of the swarm, with some random perturbations. Subsequent iteration takes place after all particles have been moved. Eventually, the swarm as a whole, like a flock of birds collectively foraging for food, is likely to move close to an optimum of the fitness function. In this situation, a single particle by itself has no way of solving the problem.

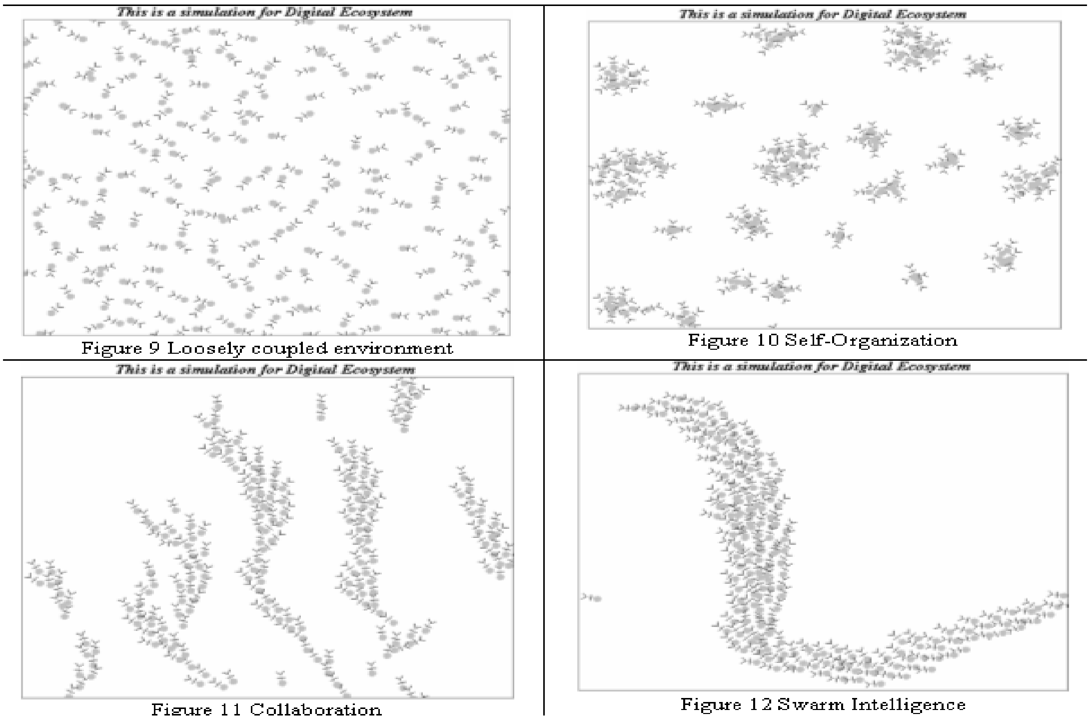


Figure 10-2: Particle Swarm Intelligent Paradigm, copied from DEBII Research Handbook 2007 and 2009

Problem-solving is a population-wide phenomenon, emerging from interactions between participants or entities or organisations; it is similar to a coral fish carrying a piece of data on its back forming a swarm on two or more dimensional planes.

In the real-world Port operation, we have logistics operators interacting within a supply chain network , which can be described in terms of the association of the social networks; their participation in the supply chain is completely self-motivated and self-organised, with the flexibility of being able to participate or withdraw. This leads to a complex optimization problem at micro level.

In Melbourne Port there are 245 carriers, which shift 740,000 containers per year. However, in Western Australia Port (WA Port), there are 162 carriers that shift 162,000 containers per year. However, WA Port's wharf has the capacity to shift 1,000,000 (1 million) containers per year.

The port operation is controlled by a computer-based Vehicle Booking System that allows all road carriers to book the pick-up and delivery of containers that come and go from the sea port. The port operation booking system:

- has 80 time slots per hour, from 6 am to 10 pm, 16 hrs/day;

- involves two main stevedoring companies, we would have 1280 containers/stevedores

- two stevedores, working 260 days/yr (not 365 days/yr), 660,000 containers/yr

If the port operate 24/7, the Road carriers can move approx. 900,000, or if 100 lots/hr, for two stevedores, 800,000, able to cope with growth of 20% in the next ten years.

The complexity of the problem is exacerbated by approximately 70 operators in the port in addition to road and rail carriers of total 162 registered business entities who operated at the port in 2010, of which 5% are large enterprises (namely 2 stevedoring companies) and 95% are SMEs.

The SMEs consistently and unanimously complain about the same things that they are unhappy with, namely, the monopoly-based control of the container movement (obviously the two stevedoring companies) and all port and road operations, which affect SMEs' productivity and result in financial losses.

Currently, there is no accepted strategy to improve the situation and move forward. We are consistently challenged when attempting to apply theory to practice. We have not found any examples of success in modelling, managing and solving such complex large-scale collaborative logistics operations; otherwise, the Port Congestion problems would have already been resolved. As described by our Prime Minister in 2011 "As the volume of trade moving through Australia's ports is expected to triple during the next 20 years"… "it is time for the way we plan and oversee our ports to change"… "The resulting bottlenecks ... are hurting Australia's economic performance, causing lower productivity, slower growth and the loss of billions of dollars in export earnings".

10.3 CHAOS THEORY IN COLLABORATIVE WORKFLOW MODELLING

10.3.1 Chaos Theory

Chaos theory can help model a non-liner dynamical system. Moreover, such a system is usually very sensitive and there are strong inter-dependencies between parties involved. With the port situation, we clearly see the local ambient sensing and reacting to each day and minutes of operations by all parties around the operators. There is an automated behaviour to either put up (wait) or fight (police are sometimes called) that each port operator uses to cope with stress at the port. As a matter of fact, this is the real situation because of the sheer number of individuals or organisations present at the port at the same time each day.

Chaos theory is a scientific approach to model the unpredictability of systems. In the world of nature, systems are largely in chaos, generating energy but without any predictability or direction, such as weather patterns, ecosystems, climate change, or business organisations. Although chaotic behaviour may appear random at first, through scientific modelling or defined mathematical formula, the chaotic system can be viewed with an order or finite boundaries.

10.3.2 The Science of Chaos

Chaos is a science of the "global nature of systems”. It crosses many disciplinary lines—from ecology to medicine, electronics, and the economy. It is a theory, method, set of beliefs, and way of conducting scientific research. Technically, chaos models are based on ‘state space,’ improved versions of the Cartesian graphs used in calculus. In calculus, speed and distance can be represented on a Cartesian graph as x and y. Chaos models allow the plotting of many more variables in an imaginary space, producing more complex imaginary shapes. Even this model assumes, however, that all variables can be graphed, and may not be able to account for situations in the real world where the number of variables changes from moment to moment.

The primary tool for understanding chaos theory (and complexity theory as well) is dynamic systems theory, which is used to describe processes that constantly change over time (e.g. the ups and downs of the stock market). When systems become dislodged from a stable state, they go through a period of oscillation, swinging back and forth between order and chaos. According to Margaret J. Wheatley in *Leadership and the New Science*, "Chaos is the final state in a system's movement away from order." When a system does reach that point, the parts of a system are manifested as turbulence, totally lacking in direction or meaning. Wheatley quotes researchers John Briggs and F. David Peat explaining the process of oscillation:

Evidently, familiar order and chaotic order are laminated like bands of intermittency. Wandering into certain bands, a system is extruded and bent back on itself as it iterates, dragged toward disintegration, transformation, and chaos. Inside other bands, systems cycle dynamically, maintaining their shapes for long periods of time. But eventually all orderly systems will feel the wild, seductive pull of the strange chaotic attractor.

Every system has the potential to fall into chaos. In complex systems, where all should fall apart, the attractor comes in, magnetically pulling system variables into an area and creating a visible shape. Because previous efforts to graph such phenomena could only be completed in two dimensions, this effect could not be visualized. However, computers now allow the phenomena of 'strange attractors' to become visible, as images of multiple dimensions representing multiple variables can finally be created.

Part of the difficulty in studying chaos theory arises because complex systems are difficult to study in pieces. Scientists' efforts to separate pieces of dynamic systems often fall apart. The system depends on each minute part of that system and the way it interacts with all other components. As Briggs and Peat state, "The whole shape of things depends upon the minute part. The part is the whole in this respect, for through the action of any part, the whole in the form of chaos or transformative change may manifest."

In the same breath, it is necessary to establish the importance of the autonomy of even the smallest parts of a system. Each component of a complex system has the ability to fluctuate, randomly and unpredictably, within the context of the system itself. The system's guiding principles (the attractors) allow these parts to consolidate over time into a definite and predictable form. This runs contrary to the impression many have of chaos theory, believing there is no order to be had in such a system. But chaotic movement does possess finite boundaries, within which is the capacity for infinite possibility. Even lacking direction, parts of a system can combine so that the system generates multiple configurations of itself, displaying ‘order without predictability.’ These systems never land in the same place twice, but they also never exceed certain boundaries.

10.3.3 **Practical Application of Chaos Theory**

Several attempts have been made to apply chaos theory to organisations. Applying chaos theory to organisational behaviour allows theorists to take a step back from the management of day-to-day activities and see how organisations function as unified systems. An organisation is a classic example of a nonlinear system (i.e., a system in which minor events have the potential to set off grave consequences or chain reactions, and major changes may have little or no effect on the system whatsoever). In order to exploit the chaotic quality of an organisation, one needs to try to see the organisational shape that emerges from a distance. Instead of pinpointing causes in the organisation for organisational problems, the company is better served, according to chaos theory, by looking for organisational patterns that lead to certain types of behaviour within the organisation.

Organisational expectations for acceptable behaviour, and the degree of freedom with which individuals are allowed to work, shape the way a company's problems and challenges are handled by its members. By allowing people and groups within an organisation some autonomy, businesses encourage the organisation to organise itself, enacting multiple iterations of its own functioning until the various pieces of the organisation can work together most effectively. An organisation that encourages this type of management has been termed a *fractal organisation,* one that trusts in natural organisational phenomena to order itself.

However, applying chaos theory to organisational practice tends to go against the grain of most formal management patterns. Order can be confused with the more popular notion of control. Defined by organisation charts and job descriptions, traditional management does not generally seek to add disorder to its strategic plan. As Wheatley states, "It is hard to open ourselves up to a world of inherent orderliness." Organisations are focused on structure and design. Charts are drawn up to illustrate who is accountable to whom or who plays what role and when. Business experts break down organisations into the smallest of parts. They build models of organisational practice and policy in the hope that this atomizing yields better information on how to improve the organisation's functioning. However, chaos theory implies that this is unnecessary, even harmful.

Self-organising systems are those that can grow and evolve freely. As long as each part of the system remains consistent with itself and the system's past, it can harness the power of creativity, evolution, and free will—all within the boundaries of the organisation's overall vision and culture. In this respect, chaos theory implies the need for effective leadership, a guiding vision, strong values, organisational beliefs, and open communication.

10.3.4 **Chaos in Port Operation**

Chaos theory is applied to a large-scale operation in Port business and enables a decision-making process to emerge to remove the congestion. The main challenge is that Port operation cannot be seen as an evolution of high-functioning teams. Each organisation may think that it is already optimised and performing well internally. The key issue is the inter-organisation collaboration. As they all compete with each other vertically or horizontally, we find it is difficult to define 'Members' of effective teams and we cannot frequently recreate the role each member plays, depending on the needs of the team at a given point. Though not always the formally-designated manager, informal leaders emerge in an organisation not because they have been given control, but because they have a strong sense of how to address the needs of the group and its members. We understand that the most successful performance is achieved not at the organisation or the individual level, but at the relationship level. We noticed that the relationship is not between the two but is n-dimensional and this relationship is in constant flux.

The dynamic economy and technology continue to change the way business is conducted on a daily basis; there is clear evidence of chaos. While businesses could once succeed despite being 'non-adaptive,' controlling institutions with permanently-installed hierarchical structures, in today's modern world, businesses find it difficult to dynamically restructure as markets expand and technology evolves. "To meet the demands of the fast-changing competitive scene, we must simply learn to love change as much as we have hated it in the past." (Liu K., Ong, T. 1999).

The creation and health of an organisation (or a system) depend on the interaction of various people and parts within that system. Similar to this, business strategies should be "just in time…supported by more investment in general knowledge, a large skill repertoire, the ability to do a quick study, trust in intuitions, and sophistication in cutting losses." Organisations lack this kind of faith (Weick Karl b. 1936), faith that they can accomplish their purposes in various ways and that they do best when they focus on direction and vision, letting transient forms emerge and disappear. We seem fixated on structures…and organisations, or we who create them, survive only because we build crafty and smart—smart enough to defend ourselves from the natural forces of destruction.

Organisations have entered a new era characterized by rapid, dramatic and turbulent changes. The accelerated pace of change has transformed how work is performed by employees in diverse organisations. Change has truly become an inherent and integral part of organisational life.

Several emerging trends are impacting on organisational life. Of these emerging trends, five will be examined: globalization, diversity, flexibility, flat, and networks. These five emerging trends create tensions for organisational leaders and employees as they experience waves of change in their organisations. These tensions present opportunities as well as threats, and if not managed well, the tensions will result in dysfunctional and grim organisational outcomes at the end of any change process. These five trends and the specific tensions they produce are presented in Table 1.

The port operators have to interact with each other since no-one wants delay or failure because it costly. Port Operation is a large-scale collaborative environment consisting typically of 200 road operators interacting with approximately 70 Port operators who reside at the port, they pay the rental to the Port Authority for the space they occupy in the port (Port Authority owns the port or land). In order to facilitate smooth operation, we set up a controlled interaction using a set of control parameters. We then evaluated the performance of the port operation network through an award program that established the average states and time period of container movement. We then conducted performance measures of the co-operated group of operators for a given time period and their status. We modelled the impact of our control strategy on the symmetry-breaking phenomenon. Symmetry breaking occurs if a macroscopic state of a system is not symmetric anymore with respect to the symmetry of the interactions. It could happen if the control strategy breaks the initial defined symmetry of interaction. We found it difficult to adapt this to the port operations and establish an optimal control strategy. Because all 200-300 operators are doing their own thing, and have their own objectives and operation policies, it was impossible to obtain any consensus of opinion.

10.4 GAME THEORY AND GROUP DYNAMICS MODEL

Friedrich Hayek describe a self-organising system as one of voluntary co-operation that responds to the spontaneous order in the dynamic market economy. Most modern economists hold that imposing central planning usually makes the self-organised economic system less efficient. Many economists adopt an intermediate position and recommend a mixture of market economy and command economy characteristics (sometimes called a mixed economy). Wiki is an example of collective intelligence through collaborative editing.

Group Dynamics is defined as an interaction among the agents within a group of collaborative entities. Group dynamics may have either a positive or negative impact on the group's performance. Interference is a typical negative effect on group dynamics. The positive synergy is spread within the group of collaborative agents when an agent intentionally supports and facilitates other agents to generate outcomes and results. Scientific methods such as 'scheduling theory' (Brucker 1998) assume task independence, and there should be no significant interference-related actions for each of the set tasks. However, group performance is significant when there is leadership but not management.

There are numerous studies that distinguish between leadership and management. The key difference is that the managers see the problems and ask why, and the leaders set the goals and vision for the near or longer term future and ask why not.

The practical modelling for group dynamics is difficult. Previous studies have been simulation-based, microscopic models such as the **Game Theory** (Parker 1997). It models each agent and the actions taken by each agent (predefined strategies and all possible moves based on payoff matrices), and the collective group behaviour can be predicted. It gives abstract features such as the number of actions and action distribution on agents.

10.4.1 **Spatial-Temporal Based Model**

The supply chain is a typical example of group cooperation and its potential problems, where group dynamics often have a critical impact on supply chain performance. The optimized performance is based on the priority of the key note in the chain as measured by the total value of supply and good delivery over time, the supply chain group of enterprises must strike to balance between the positive contribution of the highest targeted throughput tasks at the key note of the chain; otherwise, the negative reaction will interfere with the performance, resulting in time delay and poor productivity for all parties or agents involved in the chain.

10.4.2 **Spatial-Temporal Model**

Sutton's approach (Sutton Jr., S M., Osterweil, L. J. 1997) is to reduce the actions or processes that are not necessary in the supply chain, and enforce learning and adaptation to the environment we have. DAHL uses spatial-temporal properties of each agent's behaviour and their improvement to model the group performance and he allows feedback to the group to improve group dynamics and thus, minimize the negative effect and maximize the positive contribution (DAHL 2002).

The key issues in modelling the collaborative workflow through group dynamics are how to cope with 'large-scale'. Currently, the algorithm for a spatial-temporal model works purely through implicit communication and observing the effects of actions on the environment. Modelling such large-scale collaborative workflow entities encounters difficulties of modelling the communication-dependences, should an algorithm be able to model this. Several researchers have been utilising and enhancing the spatiotemporal algorithms to model the group dynamics and performance through policy-based differentiation. This approach may have brought to light the future of modelling large-scale complex collaborative workflow in the dynamics environment.

10.4.3 **Workflow Task Allocation through Specialization**

In the distributed learning algorithm (Dahl et al. 2006), Dahl demonstrated that there may be a consistent improved group performance on a cooperative transportation problem by minimizing the negative impact, such as defining the specialization of a homogeneous group and the sensitivity of crossing other groups' specialization area is reduced. For a collaborative workflow modelling, the high complexity is due to having to make an appropriate assumption about the collaboration issues to construct a workable business solution that fits all parties involved in the collaborative environment. The computational modelling approach through machine-learning methods and utility estimates that focus on the sensitive to the effects of the group interference based on the current task allocation, will pave the way for future collaborative workflow modelling.

10.4.4 **Persistence in Workflow Performance**

Dahl (2006) indicated that "Persistence with a class of tasks is a determining factor in the estimation of that class". Persistence, or inability to change, may contribute to the level of disruption in the environment, and it may lead to the general fall of the group which in turn can lead to the agent migrating to another group or tasks. To overcome this issue, we might use perceived ability of the agent to carry out the tasks and possible migration through persistence. If performance could be related to persistency, and if the group performance level has increased, it could produce a completely new environment and that may help improve large-scale collaborative workflow performance:

- Renewed set of actions (redefine some key tasks and actions for the entire workflow environment)

- Tasks nomination (allow collaborative agent to nominate to take on the tasks they wish to performance)

- Natural selection and transparencies (based on the track record and historical performance, we select the most appropriate agents or groups to take on the duties, and ensure the natural selection is transparent and published)

- Validation (continuing validation and review and repeat the above process)

We believe that the above approach will increase group and individual agent performance. A higher level simulation has been conducted and is shown in the next section.

10.5 SELF-ORGANISATION

As the world increases in complexity in the 21st century, every organisation is facing an increasingly complex environment and dynamic social and economic demands. This is due to the natural formation of large-scale collaborative environments which we see today that are largely driven by technological developments which are able to bind heterogeneous enterprises together to carry out collective complex tasks. In this increasingly complex world, we need to sharply distinguish between the things that are changing and those that remain relatively unchanged such as the principles of good management, product design methods, etc. Therefore, in this section, we have two distinct parts: (a) the traditional hierarchical management principles that are relatively stable, and (b) the dynamic collaborative workflow environment that has to be self-organised with or without hierarchical management and has to strive to survive and maximize its efficiency and productivity.

10.6 SELF-ORGANISATION MANAGEMENT PRINCIPLES

As indicated in the introduction, every organisation is facing an increasingly complex environment and dynamic social and economic needs. This complexity is due to changes, and changes affect the dynamics of the external environment. We note that some things remain relatively unchanged, such as principles of business management as described above using the MAO model, while other things are constantly changing.

In this section, we discuss how the collaborative workflow can proceed and move forward toward productivity and efficiency through self-organisation within a complex and dynamic environment.

Self-organisation occurs in all complex systems and it is not only a part of a general principle of any complex systems; we can see what occurs in our ecosystems around us, such as galaxies, crystals, canyons or coral reef. The centralized hierarchical management model in particular failed to deal with large-scale collaborative enterprises to achieve the management's objectives in a complex business environment. However, we often see that the large complex environment with or without management, has, instead of moving towards chaos, emerged and self-organised into a workable workflow environment and a workable collaborative structure or pattern to survive through continual negotiations, deliberations, explanations, communications, evaluations and revision, without a centralized management planning, command and control. These large, coherent, collaborative patterns often emerged from the local interaction of the individual enterprises which are all a small part of the large heterogeneous complex environment. The outcome of the business is achieved through parallel and distributed self-origination and management with little or no centralized hierarchical control. Analogous with natural ecosystems, we believe that human society has the ability to self-organise, self-motivate, self-serve, self-survive. These are emergent models and methods that have to be established in order to deal with complex environments, so that they can achieve the business objectives; these are beyond the capabilities of all centralized management in the 21st century.

As yet, there is no solution enabling a centralized hierarchy management to successfully control and manage the complex scale collaborative workflow environment. Self-organisation is an important component of any attempt to establish a successful collaborative workflow whenever needed. It is a self-organised network, driven by the loosely-coupled, agent-based paradigm. It emerged from bottom-up interactions, where centralized management failed to act or react on the issues or pressing problems raised within the collaborative communities. In contrast, a top-down hierarchical management is not self-organising and cannot scale up when the environment becomes increasingly complex and dynamic.

10.7 BULLWHIP EFFECT IN COLLABORATIVE WORKFLOW

10.7.1 **The Bullwhip Effect**

The Bullwhip Effect (or *Whiplash Affect*) is an observed phenomenon in forecast-driven distribution channels (Figure 10-3). The concept has its roots in J. Forrester's *Industrial Dynamics* (1961) and thus it is also known as the *Forrester Effect*. Since the oscillating demand magnification upstream a supply chain reminds someone of a cracking whip, it became well-known as the Bullwhip Effect.

Distorted information from one end of a supply chain to the other can lead to tremendous inefficiencies: excessive inventory investment, poor customer service, lost revenues, misguided capacity plans, inactive transportation, and missed production schedules (http://profit-chain.com).

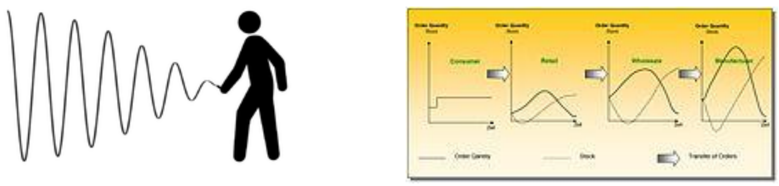


Figure 10-3: Bullwhip Effect

10.7.2 **Case study of One to One Dynamics-a Bullwhip Effect**

Assuming that the container movement follows a Stevedores-Road Transport Depots-Empty Container Parks-Road Transport Depots-Stevedores route, the stevedores can load/unload maximum 100 TEUs per day. The stevedores are capable of placing maximum 200 TEUs, the Road Carriers can carry a maximum of 100 TEUs per day, and the Empty Container Parks can place 200 TEUs. Now we compute the bullwhip effect of different extents of congestions on each player in this supply chain. Below the computation and analytics were done and supported by my colleagues(Dong, H., Chang, E. 2011) and Dong, H, Taleb A., 2011) The author of this thesis greatly appreciate their effort and support on the port project analytics.

Bullwhip effect with different extents of Zero Failure Probability

Empty Container Park (max 200)			
Hour (T)	$Stock_T$ $Stock_T = Stock_{T-1}$ - Dropped-off$_{T-1}$ + Picked-up$_{T-1}$		Occupancy Ratio = $Stock_T$/Maximum Capacity
0	200		
1	150		75%
2	100		50%
3	50		25%
4	50		25%
5	50		25%
6	50		25%
7	50		25%
8	50		25%
Road Carrier (max 100/ hour with Failure Probability = 0)			
Hour (T)	Dropped-off (max 50/ hour) Dropped-off$_T$ = 50 if To be loaded$_{T-1}$ + To be picked-up$_{T-1}$ <= 150 Dropped-off$_T$ = 200 – To be loaded$_{T-1}$ + To be picked-up$_{T-1}$ if To be loaded$_{T-1}$ + To be picked-up$_{T-1}$ > 150	Picked-up (max 50/ hour) Picked-up$_T$ = To be picked-up$_{T-1}$ if To be picked-up$_{T-1}$<=50 Picked-up$_T$ = 50 if To be picked-up$_{T-1}$>50	Efficiency= (Dropped-off+Picked-up)/ Maximum Capacity
1	50	0	50%
2	50	0	50%
3	50	50	100%
4	50	50	100%
5	50	50	100%
6	50	50	100%
7	50	50	100%
8	50	50	100%
Containers in Stevedore (max 200)			
Hour (T)	To be loaded To be loaded$_T$ = To be loaded$_{T-1}$+ Dropped-off$_{T-1}$ – Loaded$_{T-1}$	To be picked-up To be picked-up$_T$ = To be picked-up$_{T-1}$ + Unloaded$_{T-1}$ – Picked-up$_{T-1}$	Occupancy Ratio = (To be loaded + To be picked-up)/ Maximum Capacity
1	0	0	0
2	50	50	50%
3	50	50	50%
4	50	50	50%
5	50	50	50%
6	50	50	50%
7	50	50	50%
8	50	50	50%
Stevedore (max 100/ hour)			
Day (T)	Loaded (max 50/ hour) Loaded$_T$ = To be loaded$_{T-1}$ if To be loaded$_T$ < 50 Loaded$_T$ = 50 if To be loaded$_{T-1}$ >= 50	Unloaded (max 50/ hour) Unloaded$_T$ = 200 – To be loaded$_{T-1}$ – To be picked-up$_{T-1}$ if To be loaded$_{T-1}$+ To be unloaded$_{T-1}$ <=150 Unloaded$_T$ = 50 if To be loaded$_{T-1}$+ To be unloaded$_{T-1}$ >150	Efficiency= (Loaded+Uploaded)/Maximum Capacity
1	0	50	50%
2	0	50	50%
3	50	50	100%
4	50	50	100%
5	50	50	100%
6	50	50	100%
7	50	50	100%
8	50	50	100%

Figure 10-4a: Bullwhip effect with different extents of None Failure Probability (Dong etal 2011)

Bullwhip effect with different extents of 25% Failure Probability

Empty Container Park (max 200)			
Hour (T)	$Stock_T$ $Stock_T = Stock_{T-1}$ - Dropped-off_{T+1} + Picked-up_{T-1}		Occupancy Ratio = $Stock_T$/Maximum Capacity
0	200		
1	162.5		81.25%
2	125		62.5%
3	87.5		43.75%
4	87.5		43.75%
5	87.5		43.75%
6	87.5		43.75%
7	87.5		43.75%
8	87.5		43.75%
Road Carrier (max 75/ hour with Failure Probability = 25%)			
Hour (T)	Dropped-off (max 37.5/ hour) Dropped-off_T = 37.5 if To be $loaded_{T+1}$ + To be picked-up_{T+1} <= 162.5 Dropped-off_T = 200 – To be $loaded_{T+1}$ + To be picked-up_{T+1} if To be $loaded_{T+1}$ + To be picked-up_{T+1} > 162.5	Picked-up (max 37.5/ hour) Picked-up_T = To be picked-up_{T-1} if To be picked-up_{T-1}<=37.5 Picked-up_T = 50 if To be picked-up_{T-1}>37.5	Efficiency = (Dropped-off+Picked-up)/ Maximum Capacity
1	37.5	0	18.75%
2	37.5	0	18.75%
3	37.5	37.5	75%
4	37.5	37.5	75%
5	37.5	37.5	75%
6	37.5	37.5	75%
7	37.5	37.5	75%
8	37.5	37.5	75%
Containers in Stevedore (max 200)			
Hour (T)	To be loaded To be $loaded_T$ = To be $loaded_{T-1}$+ Dropped-off_{T-1} – $Loaded_{T+1}$	To be picked-up To be picked-up_T = To be picked-up_{T-1}+ $Unloaded_{T-1}$ – Picked-up_{T+1}	Occupancy Ratio = (To be loaded + To be picked-up)/ Maximum Capacity
1	0	0	0
2	37.5	50	43.75%
3	37.5	62.5	50%
4	37.5	75	56.25%
5	37.5	87.5	62.5%
6	37.5	100	68.75%
7	37.5	112.5	75%
8	37.5	125	81.25%
Stevedore (max 100/ hour)			
Hour (T)	Loaded (max 50/ hour) $Loaded_T$ = To be $loaded_{T-1}$ if To be $loaded_T$ < 50 $Loaded_T$ = 50 if To be $loaded_{T-1}$ >= 50	Unloaded (max 50/ hour) $Unloaded_T$ = 200 – To be $loaded_{T+1}$ – To be picked-up_{T+1} if To be $loaded_{T+1}$+ To be $unloaded_{T+1}$ <=150 $Unloaded_T$ = 50 if To be $loaded_{T+1}$+ To be $unloaded_{T+1}$ >150	Efficiency = (Loaded+Uploaded)/Maximum Capacity
1	0	50	50%
2	0	50	50%
3	37.5	50	87.5%
4	37.5	50	87.5%
5	37.5	50	87.5%
6	37.5	50	87.5%
7	37.5	50	87.5%
8	37.5	50	87.5%

Figure 10-5b: Bullwhip effect with different extents of 25% Failure Probability (Dong etal 2011)

Bullwhip effect with different extents of 50% Failure Probability

Empty Container Park (max 200)			
Hour (T)	$Stock_T$ $Stock_T = Stock_{T-1}$ - $Dropped\text{-}off_{T+1}$ + $Picked\text{-}up_{T-1}$		Occupancy Ratio = $Stock_T$/Maximum Capacity
0	200		
1	175		87.5%
2	150		75%
3	125		62.5%
4	125		62.5%
5	125		62.5%
6	125		62.5%
7	125		62.5%
8	125		62.5%
Road Carrier (max 50/ hour with Failure Probability = 50%)			
Hour (T)	Dropped-off (max 25/ hour) $Dropped\text{-}off_T$ = 25 if To be $loaded_{T+1}$ + To be $picked\text{-}up_{T+1}$ <= 175 $Dropped\text{-}off_T$ = 200 – To be $loaded_{T+1}$ – To be $picked\text{-}up_{T+1}$ if To be $loaded_{T+1}$ + To be $picked\text{-}up_{T+1}$ > 175	Picked-up (max 25/ hour) $Picked\text{-}up_T$ = To be $picked\text{-}up_{T-1}$ if To be $picked\text{-}up_{T-1}$<=25 $Picked\text{-}up_T$ = 25 if To be $picked\text{-}up_{T-1}$>25	Efficiency = (Dropped-off+Picked-up)/Maximum Capacity
1	25	0	25%
2	25	0	25%
3	25	25	50%
4	25	25	50%
5	25	25	50%
6	25	25	50%
7	25	25	50%
8	25	25	50%
Containers in Stevedore(max 200)			
Hour (T)	To be loaded To be $loaded_T$ = To be $loaded_{T-1}$+ $Dropped\text{-}off_{T-1}$ – $Loaded_{T+1}$	To be picked-up To be $picked\text{-}up_T$ = To be $picked\text{-}up_{T-1}$+ $Unloaded_{T-1}$ – $Picked\text{-}up_{T+1}$	Occupancy Ratio = (To be loaded + To be picked-up)/ Maximum Capacity
1	0	0	0
2	25	50	37.5%
3	25	75	50%
4	25	100	62.5%
5	25	125	75%
6	25	150	87.5%
7	25	175	100%
8	25	175	100%
Stevedore (max 100/ hour)			
Hour (T)	Loaded (max 50/hour) $Loaded_T$ = To be $loaded_{T-1}$ if To be $loaded_{T-1}$< 50 $Loaded_T$ = 50 if To be $loaded_{T-1}$ >= 50	Unloaded (max 50/ hour) $Unloaded_T$ = 200 – To be $loaded_{T+1}$ – To be $picked\text{-}up_{T+1}$ if To be $loaded_{T+1}$+ To be $unloaded_{T+1}$ <=150 $Unloaded_T$ = 50 if To be $loaded_{T+1}$+ To be $unloaded_{T+1}$ >150	Efficiency = (Loaded+Uploaded)/Maximum Capacity
1	0	50	50%
2	0	50	50%
3	25	50	75%
4	25	50	75%
5	25	50	75%
6	25	50	75%
7	25	25	50%
8	25	25	50%

Figure 10-6c: Bullwhip effect with different extents of 50% Failure Probability (Dong etal 2011)

Bullwhip effect with different extents of 75% Failure Probability

Empty Container Park (max 200)			
Hour (T)	$Stock_T$ $Stock_T = Stock_{T-1}$ - $Dropped\text{-}off_{T+1}$ + $Picked\text{-}up_{T-1}$		Occupancy Ratio = $Stock_T$/Maximum Capacity
0	200		
1	187.5		93.75%
2	175		87.5%
3	162.5		81.25%
4	162.5		81.25%
5	162.5		81.25%
6	162.5		81.25%
7	162.5		81.25%
8	162.5		81.25%
Road Carrier (max 25/hour with Failure Probability = 75%)			
Hour (T)	Dropped-off (max 12.5/hour) $Dropped\text{-}off_T$ = 12.5 if To be $loaded_{T+1}$ + To be $picked\text{-}up_{T+1}$ <= 187.5 $Dropped\text{-}off_T$ = 200 – To be $loaded_{T+1}$ – To be $picked\text{-}up_{T+1}$ if To be $loaded_{T+1}$ + To be $picked\text{-}up_{T+1}$ > 187.5	Picked-up (max 25/hour) $Picked\text{-}up_T$ = To be $picked\text{-}up_{T-1}$ if To be $picked\text{-}up_{T-1}$<= 187.5 $Picked\text{-}up_T$ = 25 if To be $picked\text{-}up_{T-1}$> 12.5	Efficiency = (Dropped-off+Picked-up)/Maximum Capacity
1	12.5	0	12.5%
2	12.5	0	12.5%
3	12.5	12.5	25%
4	12.5	12.5	25%
5	12.5	12.5	25%
6	12.5	12.5	25%
7	12.5	12.5	25%
8	12.5	12.5	25%
Containers in Stevedore(max 200)			
Hour (T)	To be loaded To be $loaded_T$ = To be $loaded_{T-1}$+ $Dropped\text{-}off_{T-1}$ – $Loaded_{T+1}$	To be picked-up To be $picked\text{-}up_T$ = To be $picked\text{-}up_{T-1}$+ $Unloaded_{T-1}$ – $Picked\text{-}up_{T+1}$	Occupancy Ratio = (To be loaded + To be picked-up)/ Maximum Capacity
1	0	0	0
2	12.5	50	31.25%
3	12.5	87.5	50%
4	12.5	125	68.75%
5	12.5	162.5	87.5%
6	12.5	187.5	100%
7	12.5	187.5	100%
8	12.5	187.5	100%
Stevedore (max 100/hour)			
Hour (T)	Loaded (max 50/hour) $Loaded_T$ = To be $loaded_{T-1}$ if To be $loaded_{T-1}$< 50 $Loaded_T$ = 50 if To be $loaded_{T-1}$ >= 50	Unloaded (max 50/hour) $Unloaded_T$ = 200 – To be $loaded_{T+1}$ – To be $picked\text{-}up_{T+1}$ if To be $loaded_{T+1}$+ To be $unloaded_{T+1}$ <=150 $Unloaded_T$ = 50 if To be $loaded_{T+1}$+ To be $unloaded_{T+1}$ >150	Efficiency = (Loaded+Uploaded)/Maximum Capacity
1	0	50	50%
2	0	50	50%
3	12.5	50	62.5%
4	12.5	50	62.5%
5	12.5	50	62.5%
6	12.5	37.5	50%
7	12.5	12.5	25%
8	12.5	12.5	25%

Figure 10-7d: Bullwhip effect with different extents of 75% Failure Probability (Dong etal 2011)

Below we present the Bullwhip effect experiment on Port Logistics Transportation Management.

Benchmarks:

- Efficiency of road carriers = Moved Containers / Maximum capacity of road carriers
- Efficiency of stevedores = (Loaded containers+ Unloaded containers) / Maximum loading/unloading capacity of stevedores

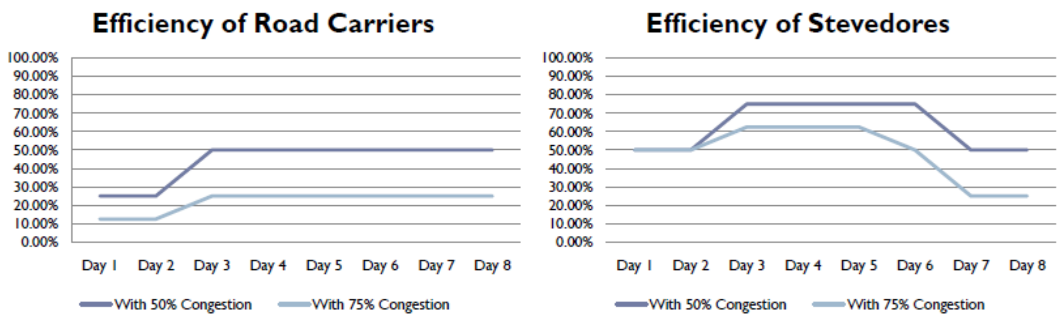


Figure 10-8: Bullwhip Effect through Congestion on Road Carriers and Stevedore

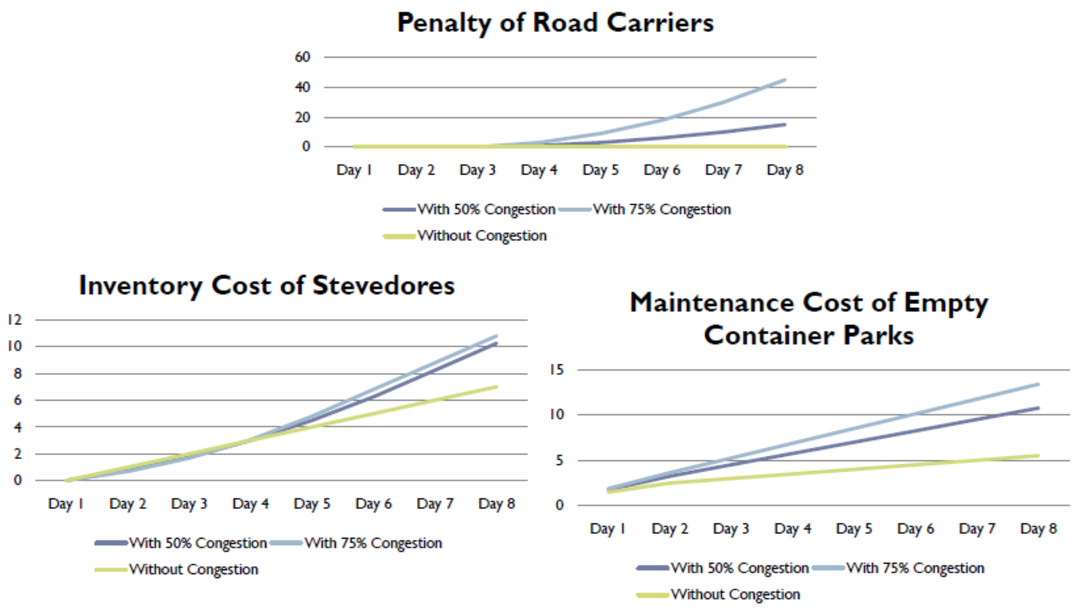


Figure 10-9: Bullwhip Effect on the Cost of the Logistics Parties (Dong etal 2011)

The bullwhip effect occurs when the demand order variability in the supply chain is amplified as goods and services move up the supply chain. Distorted information from one end of a supply chain to the other can lead to tremendous inefficiencies. The supply chain is plagued with a bullwhip effect that distorts its demand information as it is transmitted up the chain.

In the past, without being able to see the services at the distribution channel stage, a company had to rely on the service orders from the customers in order to make forecasts, plan capacity, control inventory, and schedule production. Big variations in demand were a major problem for all company management. The common symptoms of such variations could be an excessive inventory of containers that are not moving fast enough, poor logistics pick-up and drop-off forecasts, insufficient or excessive capacities, poor customer service due to unavailable information or long backlogs, uncertain truck queuing time, poor planning (i.e., excessive waiting time), and the high costs of rectification measures, such as for expedited shipments and overtime. SMEs were the victims of order swings that were exaggerated by the stevedores relative to their container distribution booking system; it, in turn, created additional exaggerations of order swings to SMEs.

Bullwhip Effect Simulation

Below we present a system simulation of the bullwhip effect on the Small Medium logistics enterprises.

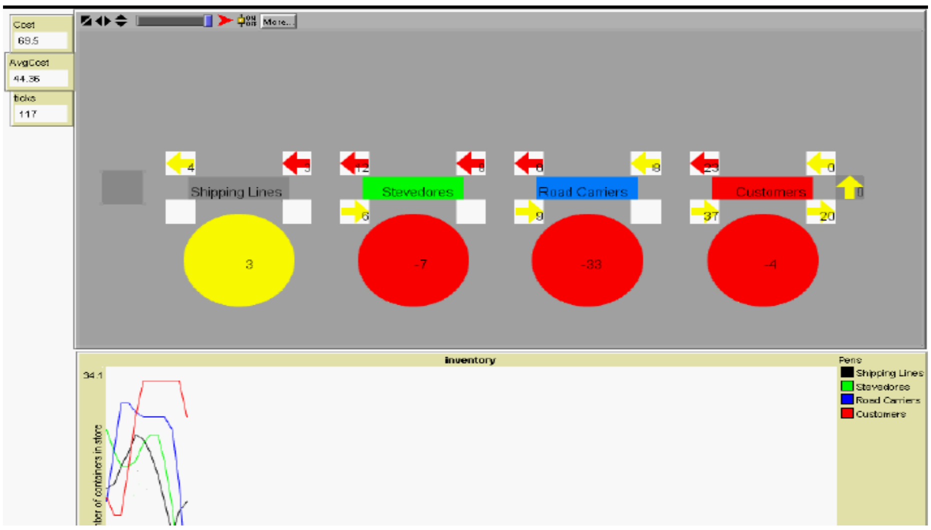


Figure 10-10: Bullwhip Simulation on Port and SMEs Logistics Carriers (Taleb., A. Dong H., 2011)

The system able to simulate the whip end for the Road Carriers which are all SMEs, and the cost increases when the workflow is congested at Stevedores.

10.8 CONCLUSION

The other area we have addressed is the self-organisation and group dynamics where, when hierarchical management practice cannot scale, and there has been no solution today to deal with large-scale complex collaborative workflow and there have been no modelling techniques available, we propose to use Game theory. This is a spatial-temporal approach to model the large-scale workflow environments, and provides a simulation result allowing this theoretical modelling approach to possibly be utilised for collaborative workflow models. We also presented the Bullwhip model for collaborative workflow modelling. The limitations of these state-of-the-art approaches have also been acknowledged in this chapter, especially the difficulties of these algorithms to scale up, and the assumptions and constraints that have to be made to be able to use the model which may not yet be able to be implemented in real-world practice. However, we believe they are the next generation of modelling tools and techniques for the analysis and design of complex collaborative workflow.

Chapter 11 - Recapitulation and Future Work

11.1 INTRODUCTION

In this chapter, an overview is presented of the research issues addressed in this thesis, and the contribution made to the research and future works.

11.2 ADDRESSED ISSUES

Previous studies have contributed a great deal to the notion of workflow, in the area of workflow modelling, design, implementation and management. Work has also been done on collaborative workflow as 'collaboration' is always easier said than done, and even more difficult in a profit-oriented business environment. Some researchers believe 'corporation' cannot co-exist with 'competition'. However, many researchers including the writer do believe in modern civilization and today's technology-enabled economy, cooperation and competition will always co-exist. Contrary to Darwin's theory that the world is moving forward by competition, we firmly believe that the world can move forward only by cooperation. Competition may play a role in the cooperation and collaboration process in order to achieve greater outcomes. This is analogous to any competitive sport. In workflow modelling, key technology includes flowcharts, or action/event diagrams or Petri-nets. These techniques can effectively and efficiently model small sections of the workflow or sub-workflow component. For a real-time large-scale workflow environment, these notation systems and diagrams need to be extended to cope with the complex environment. Numerous studies have been conducted and so far, no significant methods, models or approaches are available for large-scale complex environments. This researcher does not claim that his proposed approach will solve all the problems, or that the proposed framework will be mature enough to be applied in real-world situations. This thesis has focused on addressing the following five major issues.

11.2.1 **The Distinction between Workflow and Various Types of Collaborative Workflow**

The author has given a clear presentation of the body of knowledge relating to workflow and made a distinction between workflow and various types of collaborative workflow, and gives examples to help define the concepts and relationships between the concepts.

11.2.2 **Time Dependencies**

The author tackled the time dependencies and representation these time dependencies using activity diagrams and Petri-netsNets.

11.2.3 **Real-Time Synchronized and a Synchronized Parallel Business Processes**

Many approaches such as activity diagrams and Petri-nets can model synchronized and synchronized aspects of dynamic systems. However, they do not address real time and related real-time aspects.

11.2.4 **Inter-Dependency Relationships within the Large-scale Collaborative Environment**

Current solutions provide ‘guidance’ only on the nature of inter-dependency relationships and how to model them, and why they are important. No approach has been available to end users.

11.2.5 **Collaborative Workflow Management**

Existing solutions often fail to support a complex collaborative environment, fail to address the dynamic business environment, and fail to deal with consistent change.

To the best of our knowledge, an interdisciplinary research approach to collaborative workflow for collaborative business and corporation competition, is still in its infancy in the literature.

11.3 THESIS CONTRIBUTIONS

This thesis proposed a body of knowledge of the workflow and collaborative workflow, the management principals of the workflow and intra-, inter- and heterogeneous collaborative workflow modelling.

11.3.1 **The Body of Knowledge on Workflow and Collaborative Workflow**

The author has reviewed current approaches to workflow. The literature review provides a comprehensive, updated, technology-focused review of the state-of-the-art research in workflow and collaborative workflow.

The author also illustrates why the collaborative workflow is important in a collaborative environment, global business and dynamic economy and the key challenges for this research thesis and the future research directions.

11.3.2 **Conceptual Framework of Workflow Management**

The author has developed conceptual frameworks for the management of the collaborative workflow, including the Mao model for intra-organisation workflow management. A service-oriented framework for inter-organisational workflow and self-organisation distributed management approach for a large-scale workflow for a heterogeneous organisation. The framework has been conceptually evaluated against the warehousing, logistics and container port business operations.

11.3.3 **Intra-Organisation Collaborative Workflow Modelling**

The author has developed an extended activities diagram to model the intra-organisation workflow. Here, the author has introduced several key concepts, including worklet, workload and workflow mining. In this thesis, the modelling is built upon the concept of activity modelling through Unified Modelling Language, which aggregates workflow components and sub-components, and is demonstrated in the evaluation of a warehouse operation.

11.3.4 **Inter-organisation Collaborative Workflow Modelling**

The author shows the inter-organisation collaborative workflow by using the coloured Petri-nets. The colour represents time dependencies, and Place Transitions and Firing Rules are adopted from traditional Place-Transition Nets. The author demonstrates the approach by applying it to the logistics-warehousing industry.

However, the approach is still in need of improvement so that it can be easily adopted and applied to large-scale collaborative workflow environments.

11.3.5 **Heterogeneous Organisation Collaborative Workflow Modelling**

Using a large-scale complex collaborative environment such as a Port operation, the author clearly defined heterogeneous organisation collaborative workflow, and its distinction from an inter-organisation collaborative workflow environment. Due to the complexity of the environment, the author has proposed a scientific framework based on System Dynamics and evaluated this through system simulation and a real-world case study with Container Port Operations.

11.4 SIGNIFICANCE OF THE CONTRIBUTIONS

The **most significant** contribution of this thesis research is the Intra, Inter and Heterogeneous Organisation Collaborative Workflow Modelling techniques, and the proof of concepts using real-world case studies, namely warehouse operations, logistics and warehousing and Container Port operations.

To the best of our knowledge, this is the first research that attempts to distinguish a heterogeneous collaborative environment from an inter-organisation collaborative environment. The key distinction has been that collaborative, inter-organisation businesses are built on formally-defined partnerships, alliances or consortia, and there is a clear financial arrangement for return on investment; whereas heterogeneous collaboratively-organised businesses have no formal or financial agreement; hence, they are competitors rather than partners but have to work together and be inter-dependent in order to conduct business and make profits.

Other areas of **significance** of this thesis can be summarized as follows:

- This research explores the MAO model coupled with workflow mining for intra-organisation collaborative workflow management.
- It offers service-oriented approach to inter-organisation collaborative workflow management.
- It presents self-organisation distributed management principles for large-scale, complex workflow environment.
- The literature review provides comprehensive, up-to-date, technical reviews of the workflow modelling techniques.
- This research has realized the complexity in modelling the dynamism of the business environment. Moreover, the proposed methods and techniques will help future researchers to continue tackling the modelling issues in large complex environments.

11.5 FUTURE WORK

While this thesis has made noticeable progress in achieving scalable collaborative workflow modelling and management, there are three key areas in which more substantial work needs to be done in the future: a more open and rigorous evaluation of the proposed methods and approaches is also needed.

11.5.1 Petri-nets for Collaborative Workflow Modelling

It is understood that work needs to be done to define rigorously the 'colours' of the Petri-nets for the collaborative workflow. The author has not been able to overcome the complexity of the Petri-nets notion systems used to model a large, complex workflow. Moreover, the sample chosen for this thesis is not a sufficiently complex collaborative workflow and could not demonstrate the significance of the Coloured Petri-Net. Evaluation of the Coloured Petri-nets on collaborative workflow has not been conducted extensively because of time constraints preventing the author from evaluating this technique in terms of the results. This is further exacerbated when the scale of the collaboration increases. Therefore, a more complex sample will be needed together with a testing framework for the evaluation and proof of concept.

11.5.2 **Complex System Modelling**

Using Complexity theory for large-scale workflow modelling is an exciting and innovative research. Substantial research has to be done in order to demonstrate the significance of the proposed methods. What are the best modelling tools available through the use of Complex System modelling theory? How can the structures of the collaborative workflow be modelled? What is the proper way to express large-scale? We believe that answers to these problems provide significant input to improve the technologies for collaborative workflow modelling.

11.5.3 **Verification**

The thesis has provided some quantitative verification of the proposed techniques. However, for a large, complex, collaborative environment, because it is extensive, it was difficult to conduct qualitative 'proof-of-concept' that demonstrates the significance and contribution of the techniques. It needs extensive field testing and interviews with the end users to collect the feedback in order to find out whether or how the proposed techniques are useful and helpful. Since this thesis uses an engineering-based system development research approach, we will leave this evaluation for our future research task.

11.6 CONCLUSION

An increasing number of organisations are moving to collaborative environments and in particular, beyond inter and intra-organisation workflow environments, to solutions that involve models and workflow management systems that integrate both legacy IT assets and business partners. Since this is an emerging discipline, there exist many unsolved questions in the service community. Previous studies suggest that dynamics, complexity and large-scale have problems open for further research. Hence, this thesis approaches the problem through workflow modelling in order to solve the three major problems: dynamics, complexity and large-scale.

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