NEW HIGH VOLUME PRODUCTION, PRODUCTION LINKAGES AND REGIONAL DEVELOPMENT: THE CASE OF THE MICROCOMPUTER HARDWARE INDUSTRY IN IRELAND AND SCOTLAND

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I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of a Ph D is entirely my own and has not been taken from the work of others save to the extent that such work has been cited and acknowledged within the text of my work

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The dissertation explores the regional development effects, via production linkages, of subsidiaries of multinational enterprises that have adopted New High Volume Production (NHVP) approaches, in non-core regions NHVP approaches are positioned amid other post-Fordist forms of industrial organisation

There are literatures that suggest that the adoption of NHVP approaches will have positive implications for regional development of non-core regions because of greater indirect, backward linkage, effects Theoretically, local linkage formation or buyer-supplier proximity in NHVP industries might be the outcome of three drivers It can be driven by a search for efficiency in product flow/logistics, efficiency in formal information exchange in the context of inter-firm functional integration and by socio-cultural and institutional factors enhancing information flow in a local milieu This dissertation investigates the role of the first two drivers in shaping the geographical configuration of backward linkages in NHVP industries This is done in a case study of the microcomputer hardware industry in Ireland and Scotland

The findings of the case study do not support the positive suggestions of greater backward linkage effects A detailed examination of the supply chains of the subsidiaries of foreign microcomputer assemblers shows that the vast majority of components and parts were imported from the Far East and, to a lesser extent, the USA It is shown that efficiency in technical information exchange was a relatively insignificant driver for buyer-supplier proximity, and how this fact was related to the particular way NHVP manifested itself in the microcomputer hardware industry Similarly, in relation to most material inputs, logistical efficiency did not lead to buyer-supplier proximity It is shown that the supply chains generally involved inbound inventories, stored in local warehouses – 'hubs' – from where the manufacturing lines were supplied on a very frequent basis This logistical solution should, however, not be interpreted as sub-optimal A detailed examination of the key logistics data shows that the inbound logistics pipelines were tightly managed and that inventory levels and shipment frequencies were consistent with modern comprehensive logistics management principles

The dissertation also explores the actual impact that the NHVP plants had on the quality and competitiveness of their local suppliers in non-core regions The findings show that, although the subsidiaries of the foreign microcomputer assemblers created few local linkages, they had a significant positive impact on the quality and competitiveness of nearly all local suppliers they were dealing with

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LIST OF ABBREVIATIONS

BTO	Build-to-order
CEM	Contract electronic manufacturer
EMEA	Europe, Middle-East and Africa
EOQ	Economic order quantity
HR	Human resources
IEE	Irish Economy Expenditure
JIC	Just-in-case
JIT	Just-in-time
MNE	Multinational enterprise
NHVP	New high volume production
NLP	National Linkage Programme
PC	Personal computer
PCB	Printed circuit board
PCBA	Printed circuit board assembly
R&D	Research and development
SME	Small and medium-scale enterprise
TLC	Total logistics costs
TQM	Total Quality Management
TSCM	Turnkey supply-chain-manager

CHAPTER 1 INTRODUCTION

1 1 What is this Dissertation About?

This dissertation deals with the regional development effects, via production linkages, of subsidiaries of multinational enterprises that have adopted New High Volume Production approaches, in non-core regions It is principally targeting the discipline of economic geography, more specifically industrial geography

Industrial geography "seeks to explain the location dynamics of manufacturing activity and the local development implications of these dynamics" (Hayter, 1997, p 3) This definition incorporates two traditional themes of industrial and economic geography location and development The first theme concerns the choice situations of economic subjects, for example the location decision of an entrepreneur or a manager in a multinational enterprise The second theme primarily concerns the development of place as a geographical entity, for example a city, a region or a country Initially, the two areas of research developed distinct sets of theories – location theory and local or regional development theory – and the distinction is still being used as a way of structuring textbooks on industrial and economic geography (e g , Lambooy, Wever, and Atzema, 1997)

However, in reality the duality is no longer as strong as it was Present-day industrial geographical studies often touch both themes and contribute to a strongly integrated set of theories This can be partly related to actual developments in the way industry is organised Thus, in the chronology of plant-firm-system the region and regional development became more central (Hayter, 1997) Many studies of the industrial location behaviour of multinational enterprises (MNEs) are carried out with the aim of describing or explaining the consequences of this behaviour for the development prospects of various regions Similarly, research into the location of suppliers of MNEs and industrial agglomeration tendencies are often carried out precisely because of the importance of these issues for the development prospects of regions The merging of themes and theories is reflected in the central question of modern location theory "how and why different types of production occur at different levels of quantitative resolution in different places, and how any specific locational outcome affects the performance qualities of the economy" (Scott, 1998, p 85)

In line with the above, this dissertation incorporates both themes of industrial geography It deals with the regional development effects of subsidiaries of MNEs in non-core regions However, within this, the dissertation focuses on one particular regional development effect, the indirect regional development effect through backward production linkages It provides part of the explanation of the geography of backward production linkages This is basically an explanation of the location of industrial suppliers relative to their industrial customers, and it is here where the main theoretical contributions of this dissertation lie

The above subject can be studied from a range of theoretical perspectives Up until the mid-1980s the disciplines of economic and industrial geography had involved three broad approaches to explaining the geography of production – neo-classical, behavioural and structural approaches (Dicken and Lloyd, 1990, Healy and Ilbery, 1990, Lambooy, 1988) – although some distinguish a fourth approach referred to as the geography of enterprise (Hayter, 1997) or the systems approach (Morris, 1988) The relative importance of the three approaches has changed over time Neo-classical approaches dominated economic geography in the 1950s and 1960s, behavioural approaches in the 1970s and structural approaches in the second half of the 1970s and 1980s and, in a more moderate form, in the 1990s Before positioning this dissertation, the characteristics of the various approaches are briefly outlined below In some cases the descriptions necessarily present stereotypes of the initial contributions

The neo-classical approach explains the geography of production principally in terms of spatial variations in economic costs and revenues The rationale rests on a number of important assumptions such as perfect competition and the location decision maker as a

Homo Economicus. Using perfect information a person or a firm is assumed to calculate the optimal location in the sense of minimising costs, maximising profits or both. This calculation involves a trade-off among various location factors such as the cost of raw material, labour and the costs of distance – in the initial models mainly reduced to transport costs. Subsequently, based on the assumption of rationality, the firm chooses the optimal location. In any event, the assumption of perfect competition means that if the firm chooses a sub-optimal location it will be driven from the market. In explaining the geography of production the neo-classical approach focuses on 'purely economic' forces and pays limited attention to political, cultural, social and historical factors. Finally, since the location decision is determined by economic factors there is no need to analyse the decision-making processes or the strategies and structures of firms. The firm is treated as a 'black box'.

The end of the 1960s saw the rise of the behavioural approach. The behavioural geographers are critical of the unrealistic assumptions of the early contributions of the neo-classical approach, notably perfect information and the *Homo Economicus*. The argument is that decision-makers do not have perfect information. Furthermore many decision-makers do not always act 'rational' by choosing the economically optimal solution, but opt for 'satisfactory' solutions that meet their aspiration levels. In this view, in its search for an explanation of the geography of production the geographer should focus on the knowledge, preferences and aspirations of individuals and the decision-making processes. The initial contributions of the behavioural approach focussed on the nature of individual decision-making behaviour. However, studies into the decision-making processes increasingly revealed the important role of groups of individuals in institutions – notably in MNEs – as a variable in explanations of the geography of production. This gave rise to a new approach, the geography of production.

The proponents of the geography of enterprise (Hayter and Watts, 1983; Krumme, 1969; McNee, 1960) argued that in order to understand the geography of production one has to understand the way business organisations function. This requires an insight into and understanding of the strategies and structures of the firm and a theory of the firm. The starting point for the early geography of enterprise was the strategies and structures of large vertically integrated multi-plant corporations, believed to be the prime movers in the contemporary economy Leaning on the institutional theory of the firm industrial location decisions were interpreted as an expression of corporate strategies that in turn were formulated in the context of bargaining processes involving various institutions such as the companies' management, labour and shareholders but also rival firms, suppliers, consumers, governments and environmental groups As such the early geography of enterprise held a different view on firm-environment relations than the neo-classical and behavioural approaches Rather than treating the environmental conditions such as wage levels, taxes and government regulations as given, corporations (and the other institutions) were believed to be able to influence their environment, and with that the geography of production (Hayter, 1997)

The argument of the structural approach, leaning strongly on Marxist and neo-Marxist writing, is that economic change and the geography of production can only be understood by analysing the underlying structure of capitalist society Rather than analysing the decisions of individuals or groups of individuals the geographer should focus on the macro-socio-economic processes, the production process (in the broad sense) and the social relations of production Early structuralist geographers, such as Richard Peet and David Harvey, initially adopted a relatively orthodox Marxist approach In this view the actions of individuals and the role of space were subordinate to the underlying mechanisms of the capitalist system The early structuralists were critical of the geography of enterprise for its focus on decisions made in individual corporations rather than on the more important fundamental processes of the capitalist system (Walker, 1989) This criticism might be appropriately directed at early American contributions but is less valid when directed at contributions from other regions, such as Britain, where there was never a sharp break between the geography of enterprise and the structuralist approaches (Dicken and Thrift, 1992)

The approaches in industrial and economic geography since the mid-1980s are more difficult to classify There appears to be a degree of synthesis of the original approaches

The neo-classical, behavioural and orthodox structural approaches have disappeared in their original forms Early contributors to the geography of enterprise have adopted insights of the structural approach and in doing this have largely merged with it Many new approaches are essentially more moderate forms of the orthodox structural approach, distinguished, *inter alia*, by their views regarding structure–agency and structure–space relations Thus, the critical realist (Pratt, 1995, Sayer, 1993) and regulation approaches (Cooke, 1992, Moulaert and Swyngedouw, 1992) are both characterised by a greater appreciation of the role of agency (firms, governments, etc), space and place in analysing the geography of production while, at the same time, appreciating the role of the underlying mechanisms of capitalism Similarly, the evolutionary structural approach (Lambooy, 1988) recognises the role of actors, such as firms (both large and small) and governments, as well as of the structural conditions and mechanisms In this approach, however, there is a greater focus on the role of innovation and technological change

This dissertation incorporates elements of most approaches The dissertation deals with the regional development effects of MNEs in *non-core* regions Until the 1980s contributions in the discipline of industrial geography generally painted a rather negative picture of the branch-plant economies However, since the end of the 1980s at least some geographers are postulating that subsidiaries of MNEs might start playing a more developmental role These ideas are based on a perceived rise of flexible forms of industrial organisation and production The ideas are strongly influenced by a broader debate in the social sciences regarding a possible transition from the Fordist model of capitalist development to a new post-Fordist model and, as part of that, a transition from a rigid Fordist industrial organisation to more flexible forms There are diverging views as to what precise form this new flexible industrial organisation will take although it might be that various forms will continue to coexist alongside each other This dissertation looks *into* the development implications of one particular outcome New High Volume Production, interpreted as a new, more flexible, form of mass production

There are literatures that suggest that the adoption of New High Volume Production (NHVP) approaches by MNEs might have both direct and indirect development effects on non-core regions. This dissertation analyses the indirect development effects, in particular the backward linkage effects on the local supply base. The following problem statement guided the analysis:

> *Do NHVP approaches have significant indirect development effects in the form of linkages, in non-core regions? How does NHVP affect the geography of production linkages?*

Theoretically, local linkage formation or buyer-supplier proximity in NHVP industries might be the outcome of three drivers. It can be driven by a search for efficiency in product flow/logistics, efficiency in formal information exchange in the context of inter-firm functional integration and by socio-cultural and institutional factors enhancing information flow in a local milieu. This dissertation focuses on the role of the first two drivers in shaping the geographical configuration of backward linkages in NHVP industries. Again, the main theoretical contributions of this dissertation concern the extent and causes of local linkage formation by NHVP-adopting MNEs. An additional aim of the research project was to get more detailed insights into the actual impact that NHVP plants have on their suppliers in non-core regions. In relation to this, the dissertation also describes, in a more dynamic framework, the impact of the local linkages on the quality and competitiveness of the local suppliers.

Thus, at the broadest level this dissertation analyses the effects of changes in the model of capitalist development, in particular changes in the industrial organisation. In this lies an acknowledgement of one of the central ideas of the structuralist approaches – the idea that the organisation of capitalist society is not static and that the dynamics of the system are important for our understanding of the geography of production.

At the same time the dissertation incorporates one of the central legacies of the geography of production – the view that an explanation of the geography of production requires an understanding of the way business organisations function. In this dissertation the firm is not treated as a black box and the analysis does not stop at the factory gate. On the contrary, a large part of the dissertation is taken up by a detailed analysis of the strategies and structures of companies and the characteristics of the various elements of the value chain These issues are subsequently related to the geography of production linkages Like the early geography of enterprise this dissertation mainly deals with large multi-plant corporations However, in contrast to the early geography of enterprise, this focus is not driven by a premise that large enterprises are necessarily the only, or even most important, structuring agents in the modern economy This dissertation simply studies the spatial consequences of one particular form of industrial organisation, one that is characterised by large-scale production typically organised by MNEs

However, having laid out the changes in the overall mode of production and the related changes in the strategies and structures of companies, the analysis and explanation of the impact of these changes on the geography of production linkages feature neo-classical ideas and concepts Thus, the actual consequences of these changes for the geography of backward linkages are analysed in terms of buyers and suppliers rationally choosing an optimal location, based on a trade-off among location factors such as the cost of producing the material inputs – notably labour costs – the size of the market and distance costs The investigation focuses on the role of 'purely' economic buyer-supplier proximity drivers efficiency in product flow/logistics and efficiency in formal information exchange The analysis does not incorporate the role of socio-cultural and institutional factors in driving buyer-supplier proximity – factors that feature so prominently in the evolutionary structural approach that presently dominates the disciplines of economic and industrial geography With this interest in the more 'economic' considerations the dissertation joins other recent work dealing with the geography of production linkages around MNEs (Cooper, O'Laughlin, and Kresge, 1992, Markusen, 1996, McCann, 1998, Park, 1996, Van Hoek, 1998)

This dissertation is written with the premise that the neo-classical ideas can still contribute to an understanding of the present-day empirical reality, particularly in the context of MNEs Compared to small and medium-scale enterprises, MNEs are at least a closer representation of the *Homo Economicus* with a greater ability to collect and rationally assess data on a global basis (Hayter, 1997) Furthermore, with respect to product/flow and logistics issues, although their influence on the geography of production linkages might have been reduced at the local level, their role is still apparent at the global level This is not to say that other approaches have no value Rather, this dissertation merely focuses on different issues, *thereby aiming to* expose different elements of the overall explanation

The research followed a case study design, largely inspired by Yin (Yin, 1984, Yin, 1993) Thus, to explore the indirect regional development implications of NHVP in non-core regions four research patterns were developed, each incorporating a particular combination of views regarding the effects of the buyer-supplier proximity drivers in the context of NHVP industries in non-core regions The relevance of these patterns has been explored by looking at the case of the microcomputer hardware industry in Ireland and Scotland Most data were collected by interviewing various functionaries at the 11 branded computer makers in Ireland and Scotland Additional data were collected via postal questionnaires, documentation research and direct observation

1 2 What is New in this Dissertation?

This dissertation is original in various ways Foremost, it provides new contributions to theory regarding the geography of backward linkages in industries characterised by the adoption of NHVP approaches and the implications for the indirect development effects of subsidiaries of MNEs in non-core regions As part of this, for the first time this dissertation provides a detailed account of a relatively new and increasingly popular way of structuring inbound logistics pipelines, here referred to as 'hubbing'

The dissertation is also original in that it presents a case study of the entire microcomputer hardware industry in Ireland and Scotland Similar research has been carried out previously by Angel and Engstrom (1995) as part of their study of the personal computer (PC) industry in the USA That study reported that PC plants had very few linkages with suppliers in the USA However, the present research analyses the geography of the microcomputer industry in an entirely different context, that of subsidiaries of multinational enterprises operating in non-core regions Furthermore, in explaining the causes of limited local linkage formation by PC plants in the USA, Angel and Engstrom concentrate on the role of only one possible driver for buyer-supplier proximity efficient technical information exchange The present dissertation also investigates the role of a second driver logistical efficiency

Another aspect of this dissertation's originality is that, in analysing the geography of production linkages it, more than other studies, takes account of the interrelationships between the various elements of the value chain of a company Notably, it clearly shows the significance of the connections between customer relations and distribution, a build-to-order production strategy at the assembly plants, the inbound logistics systems and the geography of production linkages

A final aspect of originality concerns the conceptualisation of NHVP approaches Although the existence of NHVP approaches has been acknowledged for some time, this dissertation positions them more precisely amid other post-Fordist forms of industrial organisation

1 3 The Structure of the Dissertation

The dissertation is divided into 6 chapters Following this introduction Chapter 2 first reviews the existing literature and presents the research patterns that have guided this research The chapter positions NHVP approaches as a distinct post-Fordist form of industrial organisation and describes the main characteristics The main part of the chapter explores existing ideas regarding the indirect regional development effects of NHVP approaches and analyses the proposed logic underlying the idea that the approaches might drive buyer-supplier proximity Based on this analysis, the target research pattern, or hypothesis, is that the adoption of NHVP approaches will not lead to significant local linkage formation in NHVP industries in non-core regions Technical information exchange is not expected to drive proximity Similarly, although the comprehensive logistics management principles are appreciated, these principles are not expected to result in proximity

Chapter 3 outlines the research methodology Chapter 4 is the first of two empirical chapters After outlining the development of the global and regional microcomputer hardware industry the chapter determines the extent to which the microcomputer industry matches the textbook picture of NHVP The detailed analysis of the various elements of the value chain shows that the microcomputer hardware industry had many characteristics of textbook NHVP approaches However, the chapter also shows that important elements were not fully born out These findings provide an important basis for analysing the geographical configuration of the supply network This is done in Chapter 5 The chapter first outlines the geographical configuration of the supply networks of the microcomputer hardware assemblers in Ireland and Scotland and shows that the vast majority of material inputs were sourced from other continents Subsequently the role of the two selected buyer-supplier proximity drivers is analysed The findings largely support the target research scenario Supplementing the core theoretical contributions, the chapter also explores the indirect regional development effects in a more dynamic framework by describing the impact of the local linkages on the quality and competitiveness of the local supply base The conclusions are presented in Chapter 6

CHAPTER 2 LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2 1 Introduction

The post-war Fordist geography of production and regional development has long been interpreted in terms of a new spatial division of labour (Massey, 1984) or a new international division of labour (Frobel, Heinrichs, and Kreye, 1980, Perrons, 1981) Although acknowledging the reality of post-war industrial decentralisation, both theories involved strong core-periphery thinking The idea was that multi-locational companies are exploiting regional and international variations in factor endowments and factor costs by a selective allocation of functions across space MNEs in particular were seen to locate higher level command and conception activity in core regions, particularly in the home country, while lower level operations, such as labour intensive component manufacturing and assembly, took place in branch-plants located in the periphery of the national, continental or global economy

The branch-plant stereotype included labour intensive routine production, unskilled or semi-skilled labour, very limited R&D functions, external control, limited decision making power and limited local supply linkages (Pike, 1998) Their lack of integration with the local economy has been captured in the term 'cathedrals in the desert' (Grabher, 1992, Grabher, 1994, Hardy, 1998, Morris, 1992a) The peripheral 'branch-plant economies' (Firn, 1975), were seen to play a dependent role in increasingly globalised production systems, dominated by people and institutions in core regions (Ettlinger, 1992) As a result, MNE investment was believed to contribute little to a process of self-sustaining, endogenous, regional development Rather, the core-periphery relationship was locking peripheral regions in 'a permanent cycle of underdevelopment' (Scott and Storper, 1992b)

Since the end of the 1980s, new empirical evidence started to throw some doubt on the validity of the spatial and international division of labour models and related branch-plant generalisations New typologies, often strongly influenced by new insights arising out of the post-Fordist debate regarding an alleged restructuring of the sociologies and geographies of industrial organisation, suggest that branch-plants can, potentially at least, have developmental effects Thus, the 'cost or price sensitive company' is contrasted with the 'performance company' with its 'performance' or 'quality plants' (Amin, Bradley, Howells, Tomaney, and Gentle, 1994, Amin and Tomaney, 1995, Hardy, 1998, Pike, 1998) Others apply concepts such as the 'developmental multinational subsidiary' (Young, Hood, and Peters, 1994) or 'technical branch-plants' (Glasmeier, 1988) Turok (1993) juxtaposes 'developmental' and 'dependent' linkage scenarios

The structures and strategies of the 'performance' MNE are depicted as more 'localised' than those of the global American Fordist Corporation, giving rise to the concept of 'global localisation' (Cooke, 1992, Cooke and Wells, 1992, Dicken, 1994, Dicken, Forsgren, and Malmberg, 1994, Morris, 1992a) The 'new' quality branch-plants are generally presented as more 'embedded' in the local economy than their Fordist predecessors (Amin and Tomaney, 1995, Dicken et al , 1994, Grabher, 1992, Grabher, 1994, Pike, 1998, Turok, 1993, Young et al , 1994) The relatively stronger local integration allows greater responsiveness and flexibility and increases the ability to exploit local resources Because of this greater integration with the local economy MNEs would be able to function as 'growth poles' for regional development (Amin et al , 1994, Amin and Malmberg, 1994) Rather than locking regions in a permanent cycle of underdevelopment, the ideal-type quality plant has the potential to contribute to a process of more self-determined (Grabher, 1992, Grabher, 1994), self-governing and self-sustaining (Amin and Tomaney, 1995, Pike, 1998, Young et al , 1994), endogenous (Ettlinger, 1992, Hardy, 1998), regional development

The problem with the rather loosely defined (Pike, 1998) concepts such as 'performance' company/plant is that they insufficiently incorporate the fact that the post-Fordist industrial organisation can take different forms with potentially different implications for the geography of production and regional development In relation to this a growing body of academics recognises the importance of what have been called New High Volume Production approaches, existing alongside forms incorporating the idea of flexible specialisation This dissertation analyses the potential for these NHVP approaches to create new regional development possibilities in non-core regions

It is possible to distinguish 'direct and 'indirect' regional development effects of MNE subsidiaries adopting NHVP (Young et al , 1994) The direct effects mainly concern changes in the employment structure/conditions, functional upgrading of operations and consequences for the balance of payments The indirect effects mainly concern the impact on suppliers, customers, competitors and firms producing complementary goods This dissertation focuses on one of the indirect effects, the backward linkage effects on the local supply base

Section 2 2 first positions the concept of NHVP within the broader post-Fordist debate In describing the various post-Fordist scenarios, particular attention is paid to the associated geographies of production and regional development implications Section 2 3 focuses in more detail on the NHVP approaches by outlining the central principles and the consequences for various elements in the value chain Section 2 4 analyses existing theoretical and empirical work regarding the implications of NHVP approaches for the regional development effects of MNE subsidiaries in non-core regions The first sub-section deals with the indirect effects, the second with the direct effects The next three sub-section zone in on the indirect effects by looking in more detail into the logic behind buyer-supplier proximity in NHVP industries

The theoretical contributions of this dissertation concern mainly the extent and causes of local linkage formation associated with NHVP approaches Section 2 5 presents the target and rival research patterns that have guided the research in this regard The study also assesses the more dynamic impact of the local linkages on the quality and competitiveness of the supplier base Section 2 6 outlines the framework that has guided this aspect of the research The chapter finishes with a conclusion that contains the formulation of the overall problem statement as well as the presentation of the case that was selected to research the theoretical propositions laid out in the target research pattern

2 2 Fordism, Post-Fordism and New High Volume Production

The economic crisis of the mid-1970s has reinvigorated a classical debate about the dynamics of capitalism One facet of the debate involves scholars from various disciplines who are theorising a perceived transition from the Fordist model of capitalist development to a new, post-Fordist, model However, the idea of transition to a new period, a clean break, is far from universally accepted, with the critics stressing a more evolutionary interpretation leading to a new model, combining old and new elements This dispute, concerning the relevance of the idea of a clean break, represents a second facet of the debate

Post-Fordist theories of transition are informed by different approaches and cover a wide variety of themes at different levels of analysis In the first sub-section, leaning strongly on the writings of Amin (1994) and Elam (1994), I will briefly outline the way various approaches perceive the transition to a new model of capitalism and briefly outline the major themes covered in the debate One of the themes concerns the new sociologies and geographies of industrial organisation The next three sub-sections outline three views regarding the future industrial organisation and associated geographies that can be distilled from the academic literature flexibly specialised conglomerations of small and medium-scale enterprises (SMEs), flexible specialisation around large firms and new high volume production

2 2 1 The Post-Fordist Debate

The neo-*Schumpeterian approach*, strongly promoted by the work of Freeman and Perez (1988), interprets the transition between models of capitalist development in terms of 'long waves' and 'gales of creative destruction' The long waves are characterised, first, in terms of their technological content, as 'techno-economic paradigms' These paradigms are periodically overhauled in processes of creative destruction representing fundamental technological revolutions driven by a key new technology The diffusion of innovations in technology is facilitated by socio-institutional changes During the 1980s the capitalist world is presumed to have found itself in transition from a (Fordist) 'electro-mechanical / oil and petro-chemicals paradigm' to the (post-Fordist) 'information technology paradigm' The early contributions have been attacked for technological determinism and reductionism Although Freeman and Perez acknowledge the intrinsic relations between the techno-economic and social institutional spheres, in the succession of waves, "the history of capitalism remains one where 'new' techno-economic forces always do the initial acting and 'old' socio-institutional frameworks the eventual reacting" (Elam, 1994, p 46)

Piore and Sabel (1984), two of the architects of the *flexible specialisation approach*, interpret the transitory period as a 'second industrial divide' – a period where the Fordist technological paradigm is being replaced by a new technological paradigm, possibly flexible specialisation In contrast to the neo-Schumpetarian approach, the transformation is not primarily driven by technology Piore and Sabel stress that the resulting technological trajectory is not pre-determined but will be decided by social and political forces However, they tend to reduce these social and political forces to market forces The prime driver behind the current transition is seen to be the change from stable/predictable to unstable/unpredictable demand This requires, or is facilitated by, new politico-institutional constellations and new (embodied and non-embodied) manufacturing technologies

The regulation school, developed in France in the 1970s as a neo-Marxist perspective on the reproduction of capitalism The approach is broader and more politicised than either the flexible specialisation or the neo-Schumpeterian approach Building upon the critique of mechanistic and catastrophic interpretations of Marx, it acknowledges the possibility of capitalism's survival In explaining capitalist development, the Marxist focus on the mechanistic workings of economics is replaced by an appreciation of both the economic and the political structures Qualitative change within capitalism is forced by two fundamental dynamics, one giving rise to specific 'regimes of accumulation', the other to particular 'modes of regulation' Along with others, these two concepts were applied to capture the coherent system of a particular phase of capitalist development in a particular context, the crisis tendencies within the system and the development of new systems The regulationist approach is less technologically deterministic than the neo-Schumpeterian approach and less economically deterministic than the flexible specialisation approach (Elam, 1994)

Amin (1994) identifies four, to some extent interrelated, themes covered in the debate new macro-economic designs, new sociologies and geographies of industrial organisation, policy and politics, and culture and lifestyles The various approaches, and, within those, the individual contributors, have different ideas as regards the drivers of transition, the characteristics of the perceived new phase of capitalist development, and the way it should be interpreted, e g , as neo-Fordism or as post-Fordism

The focus of this dissertation will be on the second theme, i e new sociologies and geographies of industrial organisation This theme concerns the perceived transition from a rigid Fordist industrial organisation to more flexible forms As an industrial paradigm, the 'old', ideal-type, Fordism was a system of 'assembly-line-based mass production' of standardised goods (Asheim, 1992) Production took place in large vertically integrated plants owned and centrally controlled by large, often multinational, corporations Rising productivity was based on mechanisation, the pursuit of internal economies of scale, a detailed division of tasks and work intensification (Amin, 1994) Long production runs and dedicated machinery were intended to minimise down-time Driven by similar considerations, suppliers were producing and delivering standardised components in large, infrequent, batches Price competitiveness was the single most important criterion in supplier-selection (Sayer, 1986) Finally, as regards the geography of production, the narrow focus on price, production costs and labour cost minimisation meant that the Fordist system was often characterised by an extreme spatial division of labour and spaced-out supply chains Peripheral regions were incorporated in a dependent way through branch-plant investment that contributed little to regional development

The economic crisis of the mid-1970s has been interpreted as a 'crisis of Fordism' (Amin, 1994) The Fordist methods of work organisation had reached their limits in terms of productivity growth Furthermore, due to its inherent rigidities, the Fordist system was unable to cater for modern markets, characterised by increased instability and a demand for variety, quality and responsiveness The idea is that a resolution of this crisis, if possible at all, requires new, more flexible, forms of industrial organisation with repercussions for the geography of production and regional development potential There are however diverging views as to the form that this new industrial organisation and its geography will have The following sections outline three views regarding future industrial organisation and associated geographies of production that can be distilled from the academic literature

2 2 2 Flexibly Specialised Conglomerations of SMEs

One initially influential idea was that conglomerations of co-operating SMEs would replace Fordist Mass Production as the dominant mode of industrial organisation This was one of the scenarios described by Piore and Sabel (1984) They depicted a clearly *post*-Fordist scenario, a clear break with Fordism, "a shift of technological paradigm and a new system of regulation" (1984, p 252) According to Piore and Sabel, this scenario would not necessarily manifest itself and it was still possible that growth could relaunch itself on the established Fordist model However, the authors appear to believe that the first scenario is more likely – "adjustment to a world of flexible specialisation is thus the probable challenge for the US economy" (1984, p 282) Similarly, other adherents of the flexible specialisation/accumulation thesis[1] have portrayed a clear break with Fordist Mass Production (Hirst and Zeitlin, 1991, Storper and Scott, 1989)

[1] These two theses are not interchangeable (Amin and Thrift, 1992) The flexible accumulation thesis draws on the regulation approach and generally theorises a broader macro-economic design However, regarding the envisaged future industrial organisation and concomitant geography of production, the ideas of authors like Storper and Scott (1989) are not far removed from those of Piore and Sable This is partly a result of the rather eclectic theoretical framework applied (Amin, 1994, Lovering, 1990)

According to Piore and Sabel (1984), the large Fordist Mass Production corporation was unable to compete in the new market environment, characterised by volatility and increased demand, variety and quality Flexibility could be provided by flexibly specialised conglomerations of SMEs The idea is that the craft mode of production is inherently more flexible than Mass Production New production technologies, such as re-programmable computerised production equipment, are seen to support this efficiency However, the most important characteristic of flexibly specialised SMEs is the fact that they are integrated into a larger industrial structure or industrial district In the ideal type industrial district, individual firms specialise in a particular phase of the production process Assemblers will buy components, parts and services from a continuously changing group of suppliers involving flexible agreements rather than long term contracts This structure is both flexible, by virtue of its ability to continually reshape the productive process through the rearrangement of its components, and specialised, in the sense that the aim of redeployment is limited (Piore and Sabel, 1984) The district as a whole enjoys economies of scope as well as (external) economies of scale

Technological dynamism and the regeneration of resources is maintained through subtle systems that reconcile competition and co-operation Competition will stimulate innovation But this competition is necessarily limited since individual firms depend on the larger grouping for the reproduction of resources Co-operation takes place through research, educational and credit institutions, trade associations and firm networks The subtle combination of competition and co-operation requires micro-regulation that is provided through the ethnic, religious, family or other community ties and other arrangements that build trust

As regards the geography of production, proponents of the flexible specialisation/ accumulation thesis claim that flexible production will lead to a (re)-agglomeration of production in product specialist neo-Marshallian industrial districts or 'new industrial spaces' (Scott, 1998) The thesis is one of 'localisation' or a 'return to place' – a dependence on locational proximity between different agents involved in any production filière and a generalised return to the region as the basic unit of economic development

(Amin and Malmberg, 1994, Amin and Thrift, 1992) The belief in industrial agglomeration or localisation generally involves a range of agglomeration factors, although individual theorists emphasise different factors (see Table 2 1) The reasons provided for agglomeration can broadly be categorised into efficiency factors and socio-cultural factors "Some writers trace the forces that produce patterns of agglomeration to mechanisms that enhance efficiency and flexibility, while others put more emphasis on the benefits of agglomeration in terms of enhancing dynamic improvement, learning and innovation Some model the pecuniary gains that firms can yield from being close to each other, while others emphasise the role of socio-cultural and institutional structures that tend to evolve in places where a particular industry establishes a stronghold" (Malmberg, 1996, p 393) [2]

The efficiency factors, or cost-based factors, involve Marshall's established concept of external economies of scale (Krugman, 1991a, Krugman, 1991b, Marshall, 1898, Weber, 1929) The basic idea is that concentrations of production units provide advantages for individual production units in the form of a well developed base of suppliers and customers and a local pool of workers The local pool of labour presents an efficiency gain for both workers and plants by maximising job-matching opportunities and thus reducing the search costs (Gordon and McCann, 2000, Krugman, 1991a) Similarly, as regards buyer-supplier proximity, a localised industry can support more suppliers, which increases the level of specialisation and efficiency of the supply base which, in turn, presents an efficiency gain for the customers (Harrison, 1992) The key proximity drivers are efficiency in product transport/logistics and formal information exchange – the transaction costs across distance "Because of the costs of transacting across distance the preferred locations for each individual producer are those where demand is large or supply of inputs particularly convenient – which in general are the locations chosen by other producers" (Krugman, 1991a, p 89)

[2] The following section is extracted from a broader, co-authored, account of the concept of agglomeration (Jacobson, Heanue, and Van Egeraat, 2002)

These efficiency factors remain important to the formation of neo-Marshallian industrial districts and new industrial spaces However, the flexible specialisation/accumulation thesis includes an additional logic Partly informed by transaction cost theory, Scott (1998) argues that the flexible industrial organisation will be characterised by vertical disintegration and widened external transactional structures (linkages) The associated rise in transaction costs (notably the cost of information exchange involved in seeking new suppliers, renegotiating production contracts and rebuilding linkage contracts) will induce spatial agglomeration Proximity will increase the transaction efficiency, particularly in the case of those industries producing non-standardised output and characterised by a strong dependence on external, unstable production and technology linkages

Alongside these efficiency factors, the proponents of the flexible specialisation thesis stress the importance of a second group of agglomeration factors, related to proximity in a socio-cultural and institutional sense and how this benefits processes of learning and innovation (Asheim, 1992, Gertler, 1992, Malmberg and Maskell, 1997) These ideas are inspired by the work of a group of Italian industrial and regional economists (e g , Becattini, 1990) that advocated a 'neo'-Marshallian approach to industrial district analysis [3] The neo-Marshallian economists lean strongly on the original meaning of Granovetter's (1985) concept of 'embeddedness' – that economic actions of actors are embedded in social relations For several reasons this embeddedness is believed to drive proximity between economic actors First, as explained by Harrison (1992, p 478), economic actions are facilitated by trust This trust can best be built through learning about the idiosyncrasies of the actors which requires repeated personal, face-to-face, interaction Such contact is enhanced by geographical proximity

A second, more complex reason involves the entire local context or milieu, the local institutional set-up and the wider socio-cultural environment (Malmberg, 1996) In the words of Cooke and Morgan (1998), economic performance, learning and innovation

[3] The prefix 'neo' refers to the fact that the elements of Marshall's ideas stressed by this approach differ from the elements that had been stressed by the mainstream economists and regional scientists thus far (Asheim, 1992, Asheim, 1999, Harrison, 1992)

depend more and more on a capacity to support externalised relationships among economic actors – an "associational capacity" [4] This associational capacity can be strongly facilitated by a microconstitutional regulation process laying down the rules of the game – common norms, values and institutional routines The microconstitution is the basis for trust relations that may be derived socio-culturally, politically, administratively or economically It will not only strongly facilitate the formal, intentional, exchange of tacit knowledge but also knowledge spill-over Furthermore, tacit knowledge tends to become embedded in the local milieu (Malmberg, 1996) – "the mysteries of the trade are in the air" (Marshall, 1898) Actors located in other regions can not simply tap into these associational economies by maintaining face-to-face contact through frequent travel In order to enjoy the advantages actors have to be part of the milieu, and this is what drives proximity

The proponents of the flexible specialisation/accumulation thesis have claimed that the transition to a flexibly specialised industrial organisation will have positive implications for both the well-being of the individual worker and the development prospects of individual regions Flexible specialisation is seen to open up long-term improvements in working life conditions Thus according to Piore and Sabel (1984), the adversarial, hierarchical relations and routinised labour of Mass Production are believed to be replaced by collaboration and solidarity and higher intellectual participation of the worker The transition from traditional Mass Production to flexible specialisation is also believed to enhance the development prospects of individual peripheral, less favoured, regions by creating an environment more conducive to an endogenous, self-governing and self-sustaining development strategy, less dependent on external factors and resources

This scenario of an era dominated by SMEs localised in industrial districts or new industrial spaces has been criticised on empirical and theoretical grounds One of the

[4] Like many of the other authors cited in this section, Cooke and Morgan are not included here as proponents of the thesis involving flexibly specialised conglomerations of SMEs In contrast to the flexible specialisation thesis, the authors acknowledge the fact that many agglomerations will remain strongly

main critiques addresses the generality of the evidence (Amin and Malmberg, 1994, Amin and Thrift, 1992, Gertler, 1992, Harrison, 1994, Lovering, 1990, Morris, 1992a) The thesis of a (re)-agglomeration of production is supported by reference to a handful of empirical examples, mostly situated in the core areas of Western economies (Markusen, 1996, Park, 1996) The question remains whether the success of the cited examples is replicable in other regions, lacking the key ingredients of entrepreneurial culture and co-operative ethos, based on socio-cultural homogeneity Furthermore, many of the cited examples are actually controlled by large firms or subsidiaries of MNEs and many of the linkages are non-local (Amin and Thrift, 1992, Andreosso and Cassidy, 1996, Benko and Dunford, 1991, Gertler, 1988, Harrison, 1992, Harrison, 1994, Jessop, 1992, Morris, 1992b), calling into question the idea of dominance of SMEs in relatively self-contained industrial districts According to the critics, oligopolistic corporations and industrial financial groups continue to dominate and control the majority of global production systems – "oligopoly is alive and well" (Martinelli and Schoenberger, 1991)

As regards criticism on theoretical grounds, the logic involving new market conditions and diminishing internal economies of scale/ vertical disintegration has been attacked from various angles Both Jessop (1992) and Coriat (1991) argue that the conditions on which the validity of the model of flexible specialisation depends, i e markets of stable size, short life cycles and changing product composition, are limited Rather, in many cases market conditions favouring strategies based on internal economies of scale will continue to exist Others argue that the new conditions of intensified uncertainty and increased competitiveness are not necessarily translated into externalisation of activities Scott (1988) believes this is the case because large vertically integrated firms are organisationally inflexible, leading to high intra-firm transaction costs However, as Benko and Dunford (1991) point out, many large enterprises are re-organising into internally and externally networked organisations, making them increasingly flexible Furthermore, even if the new economic conditions would give rise to a process of vertical disintegration, it is far from certain that this would necessarily result in re-agglomeration,

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linked to global networks of production and they believe that subsidiaries of MNEs can be important constituents of industrial clusters and innovative milieus as Scott and Storper would want it According to Phelps (1992), although certain information related transaction costs might give rise to spatial agglomeration, the general decline in transportation costs means that production units can enjoy external economies over larger distances

2 2 3 Flexible Specialisation around Large Firms

Although most of the early enthusiasts of the flexible specialisation/accumulation thesis initially focussed on conglomerations of SMEs, a number of proponents argue that analogous changes were underway in large firms In fact, alongside the regional conglomerations of SMEs, the Japanese federated enterprise and the 'solar' firm are among the four faces of flexible specialisation described by Piore and Sabel (1984) The Japanese federated enterprise is interpreted as flexibly specialised on the grounds of, *inter alia*, its alleged involvement in craft production, its semi-integrated, non-hierarchical organisation, its sense of common identity and its interlocking personnel and financial agreements The 'solar' firms, with their orbiting suppliers, outwardly resemble the major mass-production corporations However, they are perceived as flexibly specialised on the grounds of the degree of autonomy of the suppliers and their important contribution to technology, their co-operation with the community institutions, and because of their involvement in craft production They do not produce long runs of standardised products – "their size results from the high capital requirements of their products – not economies of scale" (Piore and Sabel, 1984, p 267)

Sabel (1994) later argues that, in the era of flexible specialisation, multinational enterprises will increasingly reorganise their production on the lines of flexible specialisation, leading to an emergent corporate form which blurs the distinction between large and small firm structures The activities of multinational enterprises will resemble and actually blend into the activities of the industrial districts - "a fusion of large and small firms into industrial districts" (Sabel, 1994, p 145) Companies such as Xerox and Bosch are put forward as prime examples According to Sabel these companies are characterised by a regional reconcentration of production in decentralised units that have a high degree of autonomy. Product lines are grouped geographically. Innovative subcontractors, organised in a diversified network, are encouraged to have multiple customers in many industries, thereby enhancing their innovative capacity and reducing their dependence on one single customer. The organisational structure of this "Bosch-model" is characterised by limited vertical inter-firm organisation and hierarchy.

Likewise, Scott (1992) foresees that, in the post-Fordist era, large firms will continue to play an important role but he is less categorical regarding the idea that the post-Fordist era will be dominated by flexible specialised craft producers. He argues that the two-fold division of production units by technological-organisational type into flexible specialists (characterised by small establishment size, small batch size, low level of product standardisation, low level of routinization of the production process and short production cycle) and mass producers (with opposite characteristics) is inadequate, and that a threefold partition is needed including the notion of 'systems houses'.

Systems houses are large production units with variegated internal structures and large numbers of workers. Their size flows from massive internal economies of scope (internal synergies) often flowing from the R&D intensity of the production process. However, in other aspects the systems houses are akin to the flexibly specialised firm. On the dimension of batch size, they manufacture complex outputs in small batches with radically varying output specifications. Scott argues that these systems houses drive forward large segments of the rest of the flexible (post-Fordist) economy. Thus, according to Scott, systems houses consume a wide variety of diverse, variable and often unpredictable inputs (whereas in mass production systems the trend is towards standardisation and streamlining of the inputs as far as possible). The difficulty in standardising and routinising their input structure means that systems houses are interconnected via transactional networks with large numbers of flexibly specialised producers.

With his study of the high technology systems houses in southern California, Scott (1992) shows that the dependence on externally supplied, frequent, small batch, highly specialised, often customised and unpredictable inputs and subcontract services, leads to a dense local network of transactions focused on the systems houses – an industrial district

Both Scott (1992) and Sabel (1994) foresee a flexibly specialised or post-Fordist society, where subsidiaries of multinational enterprises can be part of, or even resemble, flexibly specialised industrial districts with positive implications for localised regional development The acknowledgement of the role of the multinational enterprise is reflected in the depiction of the geography of industrial production and regional economic development in a global context as "a mosaic of specialised regional production systems" (Scott, 1992, Scott and Storper, 1992a, Scott and Storper, 1992b) Each regional production system is foreseen to have its own system of intra-regional transactional arrangements and local labour market activities and, at the same time, will be caught up within a world-wide web of inter-industrial linkages and investment flows

The acknowledgement of the continued role of the multinational enterprise does not undermine their belief in the enhanced prospects for localised regional development, even in developing regions Thus, although they acknowledge the problem of uneven development at a world scale, Scott and Storper are encouraged by developments in the Asian and Latin American NICs, where labour-intensive and flexible production activities are proceeding apace "The experience of these regions suggests that a flexible production base, combined with effective national and international marketing organisations, can generate significant rounds of economic growth, especially where producers are able to start climbing the quality/price frontier" (Scott and Storper, 1992b, p 15-16)

The acknowledgement of the role of global capital, large firms and subsidiaries of multinational enterprises went some way towards answering the large body of criticism that some of the categorical claims had attracted However, for many it was not enough

Thus, Amin and Thrift (1992) and Gertler (1992) argue that Scott and Storper still do not sufficiently appreciate the extent of the globalisation of production Scott and Storper "have begun to talk of the future as a complex juxtaposition of local and global production networks However, this development does not draw them sufficiently far away from the localisation thesis to warrant a reformulation of their position in the debate on the geography of flexible accumulation" (Amin and Thrift, 1992, p 573)

2 2 4 New High Volume Production

A growing body of academics disputes the validity of the distinction between flexible specialisation and mass production, in even stronger terms than Scott (1992) Based on a different interpretation of often the same exemplar firms, in contrast to the more categorical claims of the flexible specialisation/accumulation thesis, the argument is that mass production still flourishes However, it flourishes in a different form, incorporating characteristics that in some ways accord with, in others differ from, the flexible specialisation model (Jessop, 1992, Morgan, 1991, Sayer, 1989) Following the example of the Japanese, many large companies are successfully competing in the new market environment with new flexible forms of high volume production that are blurring the distinction between craft and mass production (Jessop, 1992, Tomaney, 1994) These firms are not producing standardised end-products but instead have succeeded in combining mass production with product variety and customisation

Hudson refers to these new forms as New High Volume Production (NHVP) approaches (Hudson, 1995, Hudson, 1997a, Hudson, 1997b, Hudson, 1997c, Hudson and Schamp, 1995) The umbrella-term embraces a range of text-book models, such as Just-in-Time/ Total-Quality-Management (JIT/TQM) (Sayer, 1986), Lean Production (Womack, Jones, and Roos, 1990), Mass Customisation (Kotha, 1995, Pine, 1993), Time-Based-Competition (Hum and Sim, 1996, Stalk and Hout, 1990), Dynamic Flexibility (Coriat, 1991, Veltz, 1991) and Diversified Quality Production (Jessop, 1992) Although emphasising different aspects, the models basically represent different versions of a generic scenario All NHVP firms, in one way or another, "combine the benefits of economies of scope and greater flexibility in responding to consumer demand, which are characteristic of small batch production, with those of economies of scale, characteristic of mass production" (Hudson, 1997b, p 303)

Like the systems houses described in the previous section, NHVP involves large establishment sizes and, relative to classical Mass Production, small batch sizes As regards establishment size, economies of scope and economies of scale still matter (Sayer, 1989) As regards batch size, NHVP companies are producing in small batches However, where the system houses and flexible specialists focus on the production of small batches of "extremely varied products which may go through many design changes as they are in process" (Scott, 1992, 269), NHVP approaches still involve a high degree of standardisation and routinisation The degree of product differentiation is lower – flexibility of *range*, rather than flexibility of *products* (Coriat, 1991) Whereas system houses and flexibly specialised production units "consume a wide range of diverse, variable and often unpredictable inputs" (Scott, 1992, p 269), NHVP approaches still involve a high degree of component standardisation and streamlining of inputs

As regards industrial organisation, like flexible specialisation around large firms, NHVP involves a high degree of vertical disintegration in combination with strong customer-supplier co-operation However, whereas the large flexible specialist producers deal directly with a large number of constantly changing small specialised suppliers, the NHVP companies, in search of economies of scale in component production and efficiency in the co-ordination of the supply chain, aim to rationalise and stabilise their supplier base (Veltz 1991) Compared to the flexible specialisation model, the idea of NHVP involves a significantly smaller supplier base and a higher degree of vertical inter-firm organisation and hierarchy

As to the associated geography of production, NHVP operations remain strongly integrated in the global corporate networks of the multinational companies As will be outlined in the next section, NHVP does involve functional upgrading, organisational decentralisation and a transfer of autonomy to the local operations, but a strong degree of centralised control remains It is therefore difficult to see how NHVP operations can be part of 'localised', i e 'self-contained', neo-Marshallian industrial districts

Some academics (Estall, 1985, Kenney and Florida, 1992, Mair, Florida, and Kenney, 1988) have postulated that the widespread adoption of NHVP approaches might lead to a renewed drive towards agglomeration of industrial production in what might be called "clusters of NHVP" (Hudson, 1997c) However, the argument put forward by those theorising on the geography of NHVP (e g , Martinelli and Schoenberger, 1991, Schamp, 1991, Estall, 1985, Hudson, 1997c, Kenney and Florida, 1992, Lubben, 1988, Mair et al , 1988, Reid, 1995, Schoenberger, 1997) generally does not incorporate all the forces underlying the spatial agglomeration of flexibly specialised conglomerations of SMEs in neo-Marshallian industrial districts (see Table 2 1)

Table 2 1 The flexible specialisation and NHVP arguments for agglomeration

		Flexible specialisation/ neo-Marshallian industrial district argument	NHVP argument
Factors related to the labour market	A local pool of workers maximising job-matching opportunities	✓	✓
Factors related to product flow	Efficient product flow/logistics	✓	✓
Factors related to information flow	Efficient formal information exchange in the context of inter-firm functional integration	✓	✓
	Efficient formal information exchange in the context of vertical disintegration	✓	
	Socio-cultural and institutional factors enhancing formal and non-formal information flow between actors that are part of the local milieu	✓	(✓)

Like the flexible specialisation argument, the NHVP-agglomeration argument generally involves a labour market efficiency logic As regards buyer-supplier proximity, the NHVP argument also involves a product flow efficiency and an information flow efficiency logic However, the information flow argument is narrower than in the case of flexible specialisation The logic involves only the first of two new aspects of information space functional integration and vertical disintegration (Hepworth, 1989) The NHVP argument is based on the idea that proximity will enhance the efficiency in the formal exchange of information between partners, in the context of increased functional integration The strongly rationalised and relatively stable supply chains make Scott's (1988) logic, involving transaction cost efficiency in the context of increased information linkages spawned by processes of vertical disintegration, less relevant Finally, the NHVP-spatial proximity argument generally does not involve the socio-cultural and institutional factors [5] The logic is best captured in Gordon and McCann's (2000) industrial-complex model for spatial clustering, involving relatively large customer plants nurturing stable relations with relatively large supplier plants The main reason for industrial clustering is that individual firms, 'in aiming to minimise their observable spatial transaction costs, have implicitly or explicitly determined that this is best achieved by locating close to other firms within the particular input-output hierarchy of which they are part

Although the resilience and continuing success of mass production in the form of NHVP is now increasingly acknowledged, particularly by regulationist scholars, there is no consensus as to the meaning of NHVP approaches for the development prospects of non-core regions, hitherto characterised as 'branch-plant economies' Even among regulationists, disagreement remains as to how to interpret NHVP New developments within mass production industries have been interpreted as evidence of neo-Fordism, to stress a strong element of continuity with Fordism and a deepening of the principles of intensive accumulation, while others prefer to see them as one of the contours of an emerging post-Fordist era, a genuine resolution of the crisis of Fordism (Amin, 1994)

The most positive interpretations foresee a functional upgrading of branch-plants in non-core regions into more integrated business units, with continental mandates - a departure from the spatial division of labour that until the 1980s had formed the basis for allocation of functions across the globe The NHVP operations require more multi-skilled workers

[5] However, as will be explained below, in theory these factors can play a role – hence the brackets in Table 2 1

A new regime of labour relations is believed to provide better quality jobs, akin to those depicted by the flexible specialisation thesis (Kenney and Florida, 1992) Subsidiaries are portrayed as more 'embedded' in the regional economy making NHVP plants less footloose, and stimulating a process of agglomeration and self-sustaining growth in non-core regions

Being embedded is defined broadly here, as establishing a wider range of integrated functions in the region, as a greater dependence on the trained workforce and as maintaining substantial linkages with other firms in the region It is generally not used in its original meaning as defined by Granovetter and related to the importance of the local socio-cultural and institutional factors This is probably related to the earlier mentioned point that most non-core regions lack an entrepreneurial culture and a co-operative ethos based on socio-cultural homogeneity required to instigate such intense forms of embeddeness However, it is at least theoretically possible that once an initial cluster of NHVP branch-plants has developed on the basis of efficiency factors, the socio-cultural and institutional factors start to play a bigger role in the process of agglomeration and self-sustaining regional development This is what Cooke and Morgan (1998) suggest in the context of the formation of industrial clusters in Wales

Other scholars paint a less sanguine picture of the regional development effects of NHVP, or are not even convinced that Fordist Mass Production is being completely replaced by, post-Fordist, NHVP approaches Thus, Hudson stresses the continuities with Fordism and the fact that NHVP approaches will "combine 'old' methods of mass production with 'new' production concepts and practices" (Hudson, 1997c, p 470) For peripheral regions this might actually lead to a reduction in the quality of jobs and genuine functional upgrading is believed to remain limited Local linkages, according to this interpretation, remain of a dependent nature and limited in extent, partly as a result of space-shrinking innovations The overall geography of production is believed to retain strong elements of a spatial division of labour where the more sophisticated functions are allocated to core regions of Europe (Hudson, 1997c)

This dissertation analyses the impact of NHVP approaches on the development prospects of non-core regions, with a particular focus on the indirect effects in the form of production linkages The study only investigates the role of the two buyer-supplier proximity drivers that are most often put forward in relation to NHVP industries efficient product flow/logistics and efficient formal information exchange in the context of inter-firm functional integration The study does not include the role of socio-cultural and institutional issues in driving proximity although it is acknowledged that these issues might well be relevant

The next section will describe in more detail the main ingredients of NHVP, which paves the way for a more detailed theoretical treatment of the logic behind the spatial proximity argument

2 3 New High Volume Production The Main Ingredients

This section outlines the main characteristics of NHVP approaches and the way these approaches differ from classical Fordist Mass Production The abstract concept of NHVP refers to a range of flexible production models, all with their own particular emphasis The discussion below will focus on the generic elements of NHVP, identified in a detailed comparison of four text-book NHVP models JIT/TQM (Sayer, 1986), Lean Production/ Lean Supply (Lamming, 1993, Womack et al , 1990), Mass Customisation (Pine, 1993), Time-Based-Competition (Stalk and Hout, 1990) The actual description of the central principles and the implications for the elements of the value chain will however make reference to contributions of other authors, as well as to the other NHVP models mentioned in section 2 2 4

It is important to stress that this section outlines the ideal-type NHVP approaches The NHVP models coming out of the business literature are proposals for best practice operations, and "there is sometimes a dangerous slippage between descriptions of what is happening in some companies and plants and prescriptions of what ought to - indeed will have to - happen in all companies and plants" (Hudson, 1994, p 341)

Below, the main elements of the ideal-type Mass Production system are outlined first This is followed by a treatment of the central principles of NHVP in section 2 3 1 Subsequently, section 2 3 2 outlines the main consequences of NHVP for the various elements of the value chain

In this thesis, NHVP approaches are interpreted as a response to two problems encountered by the classical Fordist Mass Production firm According to Coriat (1991), these are

1) The relative exhaustion of Taylorist and Fordist methods of work organisation as sources of productivity growth
2) The new characteristics of demand that a firm faces

As regards the first problem, a summary of the line balancing problems and other rigidities of the classical Fordist Mass Production, or 'Just-in-Case' (JIC), system is provided by Sayer (1986)

1) For complex products like cars or TVs it is difficult to balance the various flows of parts and sub-assemblies into the main assembly process without gluts and shortages arising Concerns with speeding up individual machines and individual workers' action allows the creation of serious imbalances between them Paradoxically, production in exemplar companies like Ford approached nothing like continuous flow but involved a high amount of 'dead-time' Any introduction of product diversification heightens these problems
2) The JIC system entails large inventories of incoming parts and components and in-process inventories or buffers These are expensive in terms of interest charges, storage, and monitoring costs and risk of obsolescence in case of changing model specifications
3) Related to this, buffers conceal rejects and other quality problems The possibility of using another part from the buffer stock instead of the defective one and the

imperative of keeping the line moving lowers the priority given to dealing with the source of the problem Also the time lapse concomitant with the practice of producing parts and subassemblies in long runs and the physical distance between suppliers and customers, conceals the origin of problems and increases the reject rate

4) The practice of 'testing quality in', rather than building it in first time, allows significant quantities of labour and materials to be squandered on producing rejects and then on identifying and rectifying problems
5) The functionally and geographically distant, price focused, and non-interventionist relations with suppliers have disadvantages large, infrequent deliveries mean heavy warehousing and related costs, permissive attitudes to suppliers' quality control incurs costs, and the arm's-length relationships fail to encourage other kinds of harmonisation between supplier and customer, for example in the design of components
6) The JIC system requires a deep vertical hierarchy of control to co-ordinate different tasks, given that each worker generally only knows anything about a single specialised, and often deskilled job This in turn is both cause and effect of numerous but rigid demarcation lines highly complex pay structures and an overweight bureaucracy Furthermore, attempting to push specialisation to the extreme, eliminating all overlap in activities or competition between internal divisions can lead to false economy as it encourages empire building, poor co-ordination between activities, inflexibility and a lack of competitive stimulus
7) Restricting workers to single tasks under-uses their abilities, reduces motivation, increases boredom and hence fatigue, absenteeism, soldiering and resistance Rapid turnover of labour encourages deskilling and management's withdrawal of trust and responsibility from labour tends to generate behaviour that justifies such policies Separating workers by buffer stocks conceals interdependencies between workers, reducing feedback and co-operation between them Demarcation also inhibits the flexibility in restructuring because it freezes a particular technical division of labour
8) Finally, the focus on the continuity of production, coupled with the priority of quantity over quality inhibits process development, thereby foregoing possible economies

As regards the second problem, Coriat (1991) argues that demand has become far more unstable and diversified, and so almost everywhere the demand for standardised, mass produced goods is being replaced by differentiated demands for limited runs of products whose characteristics vary from one batch to another. On top of cost competition, which continues to have its own implications, is superimposed competition over quality, in the sense that keeping and winning a market today increasingly involves meeting a demand that is specified and differentiated. To this can be added that modern customers demand fast response (Pine, 1993; Stalk and Hout, 1990). In the classical Fordist, JIC, Mass Production system, efficiency is based upon uniformity and high volume production of standardised commodities. The system is inflexible and unresponsive to changes in the market and specific customer requirements - customers are sold whatever the chain produces.

In response to these challenges, the goal of all NHVP approaches is to sell the customer what he wants while, at the same time, increasing the productivity of the value chain. This has implications for a firm's entire value chain and, beyond that, for the company's upstream and downstream relations. The next two sections will outline the central principles of NHVP and the implications for the various elements of the value chain.

2.3.1 New High Volume Production: Central Principles

It is possible to distinguish three, related central principles of NHVP. All approaches aim to combine economies of scale and scope, an attack on time and speed in all business functions and integration and communication throughout the value chain.

Combining economies of scale and scope.

The aim of all NHVP approaches is to accommodate the modern heterogeneous markets, variety of tastes and demand for responsiveness. This requires that companies increase and frequently replace their model variety In principle, the classical Mass Production system would be able to provide variety by operating multiple lines, each producing a different model in long runs However, the rigidities of the production system and complexity of the scheduling function, in combination with the need to be responsive in an uncertain and volatile market environment means that the costs of providing variety in this way would rise, particularly due to rising inventory levels

In response to the dual challenge NHVP approaches provide variety through a system that combines the benefits of economies of scope (characteristic of small batch production) with those of economies of scale (characteristic of mass production) (Hudson, 1997c) At the same time, inventory levels and risk of obsolescence are reduced through a combination of manufacturing and logistical solutions Thus, all NHVP models prescribe a reduction of the average batch size, or "a highly integrated series of small lot production processes ( ) on the same production line" (Sayer, 1986, p 55-56) In fact, the Mass Customisation approach advocates the production of individually customised products, or 'lot sizes of one' (Pine, 1993) However, elements of economies of scale, and other characteristics of classical Mass Production, such as standardisation of components, are retained at various places in the value chain As Schamp points out, in relation to automobile production, "the difference from earlier mass production does not consist of a renunciation of scale economies, but of their displacement from the stage of final assembly to the prefabrication stage" (1991, p 162)

Time as a central strategic factor

All NHVP approaches share a recognition of the strategic role of time for competitive advantage This recognition has been expressed through various catch phrases, most explicitly through the business mantra of "Time-Based-Competition" (Stalk and Hout, 1990) The JIT/TQM approach, advocates the elimination of idle time (Sayer, 1986) and Dynamic Flexibility calls for the elimination of dead time (Coriat, 1991)

This increasing significance of time is driven by both demand and supply side factors Firms are facing an increased demand for responsiveness and a shortening of the product life-cycles (Veltz, 1991) As a result, firms increasingly need to work towards a faster introduction of new products and a faster throughput and delivery of existing products (Schroeder, 1993) On the supply side, time is accorded a central role in the road towards productivity growth The idea is "to convert dead time into time that is actually productive, whether the dead time relates to workers, the rate of use of machines, or the time in which raw materials and semi-finished goods are stored" (Coriat, 1991, p 136) This idea applies beyond the individual manufacturing plants or company – "reducing time throughout the value chain is key to Mass Customisation" (Pine, 1993, p 137)

A systemic model

Strongly related to the previous principle, all NHVP approaches are characterised by what Veltz (1991) calls a 'systemic model' – an integrated cycle from design to distribution in an interdependent system The systemic model is partly a response to the problems associated with the functional divisions and rigid, hierarchical, organisational structures of classical Fordist Mass Production that proved increasingly unable to live up to the new requirement of responsiveness Instead, the systemic model is characterised by strongly integrated and flattened organisational structures that facilitate greater responsiveness

Furthermore, integration is seen as a new way of achieving productivity gains (Coriat, 1991) Greater communication reduces the need for buffers, allows for 'simultaneous development' (Womack et al , 1990) and problems or bottlenecks will be detected earlier than is the case with the sequential practices of classical Mass Production Furthermore, integration and communication between the various functions allows for a fuller use of human resources at all levels in the organisation Productivity gains are often attributed to automation However, the impact of these modern technologies on productivity is for a large part a reflection of their communicational component and the powerful process of integration that results (Coriat, 1991, Veltz, 1991)

The principle of integration through communication applies to individual companies as well as to the companies and their environment - to its suppliers and customers The latter type of integration is referred to as supply chain management (Christopher, 1992), supply chain integration (Stalk and Hout, 1990) or value chain integration (Pine, 1993) These network integration processes involve commercial, logistics and production functions as well as design functions

2 3 2 Implications for the Elements of the Value Chain

Here, the main characteristics of NHVP enterprises will be outlined under five headings customer relations, product development, the final assembly plant, corporate organisation and the supply system

Customer relations and distribution

The dual challenge of increasing variety and productivity are addressed by a combination of production and outbound logistical solutions All NHVP approaches stress that flexibility requires a streamlined, strongly integrated, delivery system characterised by inter-company partnership Although there will be a constant pressure to reduce prices and cost, price negotiations are characterised by strong partnership, rather than cut throat negotiations Communication involves a constant exchange of information about current and forecast end-customer demand and product development plans

Much attention is paid to the reduction of time consumption in the delivery system, which is seen to increase responsiveness, flexibility and productivity (Hise, 1995) One obvious way is through a reduction in the physical distance to the customer Other strategies involve a reduction in the organisational and communication layers in the delivery system (Milne, 1990) In this regard direct sales/shipment strategies will reduce the time lost to double handling as well as facilitate closer producer-customer relations

As a general way of retaining efficiency in the supply of high product variety, NHVP approaches involve a strategy of retarded differentiation (Coriat, 1991), also referred to as postponed manufacturing (Van Hoek, 1996, Van Hoek, 1998) or deferred assembly (Cooper, 1993) In general, it means carrying out of differentiation as late, or as close to the actual need in time, as possible This will increase the overall efficiency of the value delivery system because it allows for scale economies in the high volume production of standardised components and a reduction of inventory holding costs The strategy can involve the outbound logistics function, a situation that has been referred to as value added logistics (VAL), smart distribution, or value added distribution (Christopher, 1992, Forfas, 1995a, Forfas, 1995b, Persson, 1995, Van Hoek, 1996) In this case the final differentiation activities are decentralised from the global manufacturing plants to a VAL centre, located near the final market which will allow for a further postponement of the differentiation

Product development

All NHVP approaches stress the importance of innovation for long-term competitiveness and survival They all call for a reduction in the time it takes to design and introduce new products Thus, the median age of product offering becomes a key management parameter (Stalk and Hout, 1990) Attention is not limited to product innovations, the importance of process and business innovations is emphasised as well In contrast with classical Mass Production, which focused on breakthrough innovations, the NHVP approaches stress the importance of continual incremental innovations, as part of a broader framework of *kaizen* – continuous improvement involving everyone

The success of this strategy depends on high levels of organisational integration The focus of Mass Production on breakthrough innovations resulted in a separation of the innovation and production function In contrast, NHVP approaches prescribe the integration of innovation and production Isolation of development functions, even those involved in the advanced technologies, from the day to day workings of the company is to be prevented The relevant development resources from various functional areas (including sales and marketing, planning and factory operation) are brought together in a team, preferably under one roof in close proximity to the production plants (Pine, 1993, Womack et al , 1990) The individual team members retain ties to their functional departments One of the great benefits of such organisational integration is that it facilitates simultaneous development (Womack et al , 1990) Product, part and process development can take place simultaneously rather than sequentially, as is the case in Mass Production, which reduces the time it takes to develop and introduce new products Another advantage is that the involvement of factory operations will mean that the manufacturability of design receives due attention from the outset (Handfield, 1993)

The assembly plant

An increase in the variety reduces the possibilities for economies of scale, in the strict sense Furthermore, when the level of variety or customisation increases, one of the main challenges for the assembly plant is to control the process complexity and inventory handling costs In the NHVP assembly plant these challenges are addressed by a combination of flexible processes, work practices and technologies and product engineering strategies that allow, as much as possible, for the retention of economies of scale and introduction of new economies of range or scope as well as other efficiency gains

Product engineering strategies aim for the modularization of components that can be configured into a wide variety of end products There are various forms of modularity, that can be combined in one and the same company (Cooper, 1993, Pine, 1993) NHVP approaches often involve a combination of component-sharing modularity, where the same component is used across a variety of end products, and component-swapping modularity, where different components are paired with the same basic product Through a strategy of component modularization, economies of scale are gained in the production of standardised components rather than in the final assembly process However, even in this stage, economies of scope or range (Coriat, 1991) can be gained through the use of flexible machinery and automation (Schamp, 1991) Apart from increasing the variety of products on offer, modularization will also facilitate speedier product development

The standardisation, and reduction of the necessary components and parts – or product simplification (Phelps, 1993b) – goes some way towards solving the line balancing and inventory problems encountered by the classical Mass Production plant However, in addition, NHVP approaches involve various forms of flexibility to increase efficiency and productivity in the production process[6]

Flexible machinery as well as other, low tech, solutions significantly reduce the set-up times and thus the waste of time and resources between production runs On a system level, flexible manufacturing systems integrate various phases of the overall production process, including design and distribution Much celebrated in this regard is the JIT production system Instead of producing at maximum volume in long runs, the essence of this system is that work is only done when needed, in the necessary quantity at the necessary time (Sayer, 1986) The reduction of the length of the individual production runs and the concomitant reduction in buffer stocks, means that faults in individual components will be detected earlier, thus reducing total quality costs (see section 2 4 4) (McCann, 1998) The reduction of in-process buffers, or inventory levels, is both a requirement and an advantage of the system Furthermore, the system reduces planning, information-handling and supervision costs and cycle times

[6] At the same time, NHVP retains a number of rigidities and should therefore not be equated with flexible production (Gertler, 1992, Gertler, 1988, Hudson, 1997c, Sayer, 1989)

Although JIT production systems have the flexibility to deal with small fluctuations in volume, a highly irregular and unpredictable sequence of pulls from final assembly would lead to inefficient use of labour and machinery upstream Therefore output has to be smooth enough, and production planning accurate enough, to enable the number of workers and the size of work-in-process inventories to be minimised without risking hold-ups or periods of zero productivity (Sayer, 1986)

Preferably a JIT system should be followed right to the front-end of the production process, i e products should only be produced when ordered and at the latest possible moment Such a 'build-to-order' or 'make-to-order' system with short lead times (Handfield, 1993, Pine, 1993, Schroeder, 1993, Stalk and Hout, 1990) facilitates responsiveness and customer choice and significantly reduces the inventory costs and risk of obsolescence

Flexible manufacturing systems are highly sensitive to error, rejects or stoppages, an extra motive for the emphasis on quality in JIT/TQM and other NHVP approaches Preventative measures reduce the occurrence of error Systems are in place for detecting defects and for tracing problems to their ultimate cause If problems do occur they are solved immediately, in process In the framework of *kaizen* – continuous improvement involving everyone – operators carry out preventative maintenance and contribute to problem solving

Productivity is also enhanced by a more flexible use of workers (Gertler, 1988, Sayer, 1989) Flexible labour markets or numerical flexibility, i e the use of overtime, part-time employment and temporary workers, enables NHVP firms to adjust the aggregate quantity of labour used in production in response to fluctuations in demand, thereby preventing waste through surplus workers Flexible working practices, or functional flexibility, involves individual workers performing a wider variety of tasks This might mean carrying out certain maintenance tasks, operating several semi-automated machines at the same time or carrying out a fixed cycle of different operations (Sayer, 1986) In every case the intensity of work, and thus productivity, is increased Furthermore, according to the proponents, such practices will lead to more involved workers, a fuller use of the various resources of each worker, less boredom and a reduction in labour turn-over

Corporate organisation and subsidiary roles

The era of Mass Production was characterised by a variety of corporate organisational structures In relation to this, Bartlett and Ghoshal (1989) distinguish the 'multinational', the 'international', the 'global' and 'transnational' organisation structure [7] The prototypical American Mass Production corporation had an international or, later, a global organisation structure Both forms were characterised by a high degree hierarchy and centralised control from parent headquarters over the subsidiaries The 'global' organisation involved a centralisation of assets, resources and responsibilities, with subsidiaries assembling and selling products and implementing plans and policies developed at headquarters Other corporations, including many continental European ones, had more decentralised organisation structures, akin to the multinational organisational form Here, world-wide operations were viewed as a portfolio of national businesses Subsidiaries had significant authority and autonomy, although this was often limited to the host country in which the subsidiary operated (Young et al , 1994)

Few NHVP models are explicit as regards the most appropriate corporate organisational form The models are strongly inspired by the success of Japanese corporations that until the end of the 1980s, did not provide a blue-print for international operations Most Japanese corporations had few overseas operations Assembly and component manufacturing activities were still mainly located in Japan and international markets were served via exports Of the NHVP approaches discussed, Womack *et al* (1990) provide the most detailed proposals for international organisation structures 'post-national' companies involved in 'multiregional production' These proposals were inspired by a

[7] The description in this section of the categorisation of organisation structures and subsidiary roles by Hedlund and Rolander, White and Poynter and Bartlett and Ghoshal is strongly based on the overview article by Young et al (1994)

small number of Japanese automobile companies that had gone furthest towards establishing a truly global corporate structure

Multiregional production involves the creation of 'top-to-bottom', paper concept to finished product, manufacturing systems in the three mam markets of the world – the global 'triad' (Ohmae, 1985), i e North America, Europe and East Asia At the same time, on a regional level, operations will be spatially centralised in one location, away from the practice of some Mass Producers to operate assembly plants in various national markets Schoenberger (1997) envisages a similar configuration in relation the rise of time-based-competition Competing in all major markets provides economies of scale in component production, denies competitors exclusive markets and provides protection against regional cycles Production in or near the market of sale is seen as a requirement of a truly lean distribution sales and service system, particularly if a build-to-order strategy is adopted Such a structure directly reduces the time to customer and the outbound logistics costs, will shorten the planning cycle and, therefore, reduces uncertainty At the same time, consumer requirements differ by region and the multiregional presence allows companies to 'be in touch' with their customers Finally, the structure is seen to provide protection from trade barriers and currency shifts

The ideal 'post-national' company will develop a set of products unique to each major region These will be produced within individual regions to serve the volume segments in each region These products will then be exported to other regions to fill market niches The majority of demand is met by the production system in each region and cross-regional trade is reasonably balanced

The associated organisation structure should be one that "functions smoothly on a multiregional basis and gains the advantage of an insider in each of the major regions At the same time, it must benefit from access to systems for global production, supply, product development, technology acquisition, finance, and distribution" (Womack et al , 1990, p 218) The authors do not present a detailed blueprint for organisation structures but argue that becoming an insider in a region and smooth operations requires substantial decentralisation On the other hand, co-ordination and centralisation is required to avail of certain economies of scale and savings through standardisation in assembly and component production/development as well as savings related to company-wide consolidated purchases The suggestions include a mechanism for co-ordinating the development of new products in each region and an integrated global personnel system The authors argue for an organisation structure that is neither extremely centralised, nor extremely decentralised As such, the organisation structure lies between the global and the multinational structure

The organisation structure has many characteristics of that of the transnational organisation, Bartlett and Ghoshal's fourth organisational form The transnational is described as "an integrated network organisation with some resources centralised in the home country, others distributed among national operations and all integrated through strong interdependencies" (Bartlett and Ghoshal, 1989) The post-national company has less in common with the less centralised, less hierarchical, 'heterarchical MNE', as described by Hedlund and Rolander (1990) This involves loosely coupled political systems rather than tightly bonded, homogeneous, hierarchically controlled systems The heterarchical MNE may have many centres with notions such as headquarters, home country and corporate level disappearing

Within the new organisation structures, subsidiaries have acquired a different role White and Poynter (1984) have characterised the subsidiaries of the Mass Production era as 'rationalised manufacturer' and 'miniature replicas', a scaled down version of the parent, chiefly involved in assembly work – the archetypical branch plants The subsidiaries of the post-national company are more akin to White and Poynter's 'product specialist' subsidiaries holding world or continental product mandates A subsidiary that possesses a continental product mandate is given continental responsibility for a complete range of value activities, managing ('local-for-local') R&D, production and marketing activities for a product continentally In contrast, the subsidiaries of the heterarchical MNE probably have more characteristics of the 'centres of excellence' These subsidiaries have responsibility for one element of the value chain only, e g finance, manufacturing, R&D or logistics (Young et al , 1994)

The supply system

NHVP involves strong corporate vertical disaggregation At the same time supply chains are characterised by high levels of vertical co-ordination Part supply is neither in-house, nor arm's length (Womack et al , 1990), a situation that has been referred to as 'vertical near integration' (Veltz, 1991) or 'vertical quasi-integration' (Lamming, 1993) Near integration serves, *inter alia*, two purposes it enhances efficiency and flexibility in logistics and in product/process development (Stalk and Hout, 1990)

As regards logistics, the central principles of the JIT manufacturing philosophy also apply to the way companies manage their supply chain In order to reduce 'total logistics costs' and 'total quality costs' (see section 2 4 4), companies work towards small and frequent orders, just-in-time supply and a shortening of the supply lead time, without, however, transferring the burden of inventory to the suppliers This means that a JIT system for delivery requires that the suppliers, in turn, have to adopt JIT manufacturing practices (Sayer, 1986) Furthermore, as explained before, JIT supply cannot deal with a highly irregular and unpredictable sequence of pulls from the customers since this would lead to inefficient use of labour and machinery upstream, at the suppliers

As for product development, in the prototypical vertically integrated Mass Production corporation most product development and strategic part supply was kept in-house Relations with suppliers tended to be arm's length Most suppliers were not involved in product development but were provided with a blueprint for production Other suppliers produced catalogue goods (Hayter, 1997), again involving limited supplier-customer co-operation Supplier-assembler relations were largely regulated through the market and competition amongst suppliers was price-based The arm's length relation left the innovative resources of the suppliers largely underdeveloped and unused This supply model proved increasingly unsuitable for a strategy of rapid and continuous product introduction

Instead, NHVP companies aim to more fully exploit the development resources of the supply-base As the diversity and sophistication of component technologies increase, assemblers increasingly rely on their suppliers for innovation and product and process development NHVP involves a joint approach to product development (Lamming, 1993) The development systems of suppliers and customers are strongly integrated and suppliers are involved in product development from an early stage This allows for the development activities m both companies to take place in parallel or synchronous, rather than sequentially (Hamilton, 1995, Lamming, 1993, Pine, 1993, Sayer, 1989)

These product flow and product development systems require supply chain management (Christopher, 1992) and supplier co-ordination (Rich and Hines, 1997) NHVP involves a constant personal and instantaneous electronic communication of technical and commercial information about stock data, current demand for end-products, short-term demand forecasts, future wants and needs, coming product development projects and continual interaction on quality and product development Assemblers and suppliers share logistics systems and information technology These systems of communication take time and resources to develop Furthermore, in return for their greater commitment of resources towards product development, suppliers are looking for a greater share of customers' business For both reasons, NHVP companies rationalise and stabilise their supply bases (Veltz, 1991) The traditional practice of multiple sourcing is replaced by the use of single suppliers and longer-term supply relationships On a global scale corporations consolidate the purchases of inputs common to their different plants (Lamming, 1993, Phelps, 1993b, Womack et al , 1990) In one sense, the longer-term, collaborative supplier relations reduce flexibility, since relations cannot be broken according to short-term market signals[8] (Sayer, 1989) However, the stronger integration

[8] On the other hand, textbook Japanese NHVP firms have been reported to practice 'parallel sourcing' In order to protect themselves against opportunism very similar parts for different models are provided by a range of suppliers Individual models might involve 'sole-source suppliers', but assemblers are able to

facilitates greater flexibility and efficiency in production, inventory management and product development

Thus, the various functional levels in customer and supplier firms are strongly integrated In industrial organisational terms, the supply relations are typically referred to as 'networked' There are, however, networks and networks Langlois and Robertson (1995) distinguish two basic types of networks core networks and decentralised networks Core networks, or strategic networks (Sydow, 1992), are organised around a single lead firm, usually a large assembler The satellite firms supply intermediate inputs to the core, which effectively co-ordinates the network as a whole The standards of compatibility of the individual components of the various suppliers are laid down by the lead assembler and may differ from assembler to assembler Decentralised networks on the other hand, do not have a lead firm Compatibility of components manufactured by suppliers is ensured by standards that are determined jointly by component producers and assemblers through market processes or negotiation

NHVP approaches tend to involve core networks with a high degree of co-ordination by the assembler Business concepts such as supply-chain-management, supplier co-ordination and supplier development (Rich and Hines, 1997) all imply a leading role for the assembler in co-ordinating its supply-base "Every chain needs a leader" (Stalk and Hout, 1990, p 234) One oft-cited model in the NHVP literature is that of the Japanese *keiretsu*, as exemplified by the *Toyota Motor Company* (Lamming, 1993, Pine, 1993, Sayer, 1989, Stalk and Hout, 1990, Womack et al , 1990) The *keiretsu* consist of lead firms and their dependent supplier firms, organised into tiers Although vertically disintegrated, the supply chain is characterised by a degree of mutual shareholding, so ownership disintegration is not total The *keiretsu* are largely hierarchical, 'closed' and tend to be dominated by a single buyer (Sayer, 1989), although the structure of at least some keiretsu is changing with suppliers serving customers in competing keiretsu (Sabel, 1994) The tiered structure means that the lead firms are exempted form the burden of

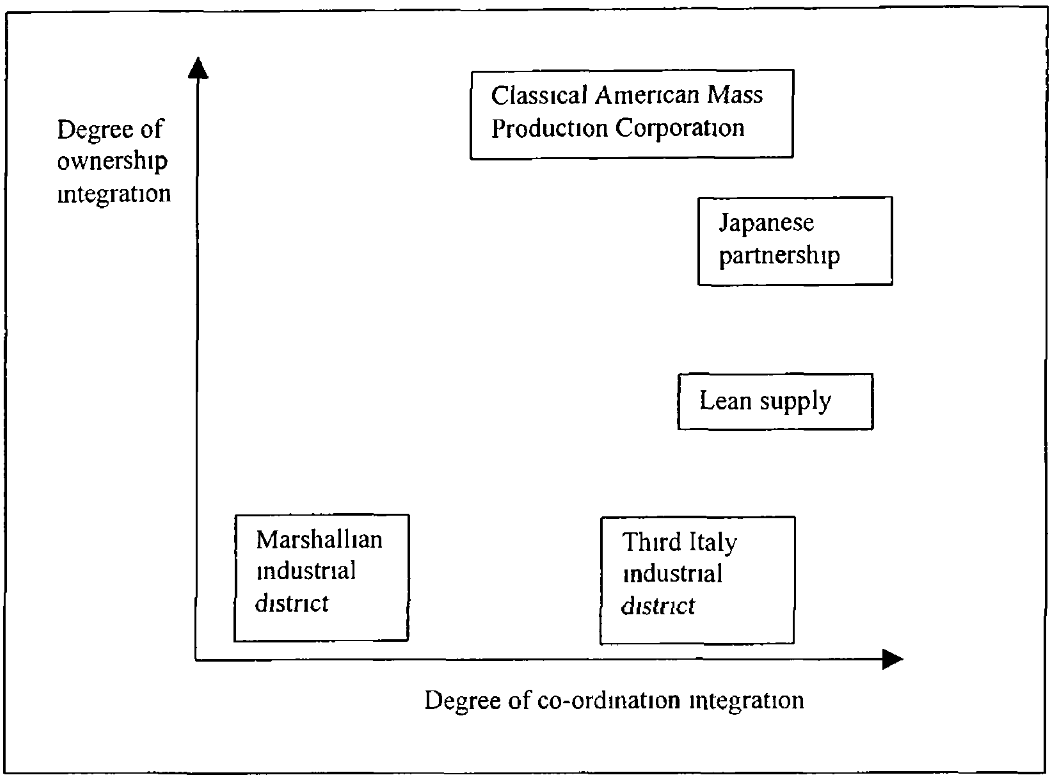
switch orders among existing suppliers without great difficulty (Hirakubo and Kublin, 1998, Langlois and Robertson, 1995) managing a myriad of individual suppliers since the first tier suppliers are responsible for a large part of the management of the second tier of suppliers Compared to the system of Mass Production, in the Japanese partnership model suppliers are more involved in the product development efforts of the assembler However, technology is led by the customer – "the roles of customer and supplier remain senior and junior" (Lamming, 1993, p 208) Furthermore, the assembler does not delegate the design of parts considered vital to the success of the final product Design and manufacture of these parts is reserved for the in-house supply divisions (Hudson, 1997c, Womack et al , 1990)

The Japanese partnership model as outlined above is not the only possible model for supplier relations in NHVP Various scholars have suggested a new best practice model called 'Lean Supply', based on Japanese Partnership but developed for global operations (Lamming, 1993, Womack et al , 1990) One of the main characteristics is that the supply chains are more 'open' and relatively less hierarchically organised Suppliers are still organised in tiers but not in the sense of the integrated ownership structure of the *keiretsu* Rather, suppliers are organised in groupings or associations formed by collaboration for specific supply purposes Individual first-tier suppliers have close links with one customer, but at the same time have more distant, but still important, links with other customers Similarly, unlike the Japanese Partnership model, the Lean Supply model allows for the entry of new suppliers, although, existing suppliers will first be given the chance to adapt The assemblers, competing on a global scale will have to avail of the wide choice of resources available in the global industry The senior-junior customer-supplier relation has been replaced by a relation between equals and the technology is the product of the collaboration of the supplier and the assembler as equals Part suppliers supply their own technology developed in close co-ordination with the assembler Assemblers even give up control over parts that in the partnership model would have been assumed the natural preserve of the assembler and the supplier may become the technology leader in its own specialist area (Lamming, 1993)

Following Langlois and Robertson (1995) and (Hayter, 1997) it is possible to categorise the organisational arrangements outlined above according to their degree of ownership integration and co-ordination integration This is illustrated in Figure 2 1 One extreme, involving low ownership integration and low co-ordination integration, is represented by the classical Marshallian industrial district The neo-Marshallian industrial districts in the Third Italy are characterised by a higher degree of inter-firm co-ordination integration The classical American Mass Production corporation is characterised by a high degree of ownership integration with most product development and strategic part supply kept in-house Intra-firm structures were designed to facilitate high levels of co-ordination However, to the extent that suppliers were used, the degree of co-ordination integration could be very low, as in the case of catalogue goods *Prima facie* the Japanese partnership model has a more disintegrated ownership structure, but the mutual shareholding arrangements mean that there remains a relatively high degree of ownership integration Co-ordination integration remains high, both inter-firm and intra-firm The Lean Supply model involves a lower degree of ownership integration but co-ordination remains high

Thus, in a sense, the Lean Supply model moves closer towards that of the flexibly specialised neo-Marshallian industrial district However, important differences remain Firstly, the assemblers and most of the first-tier suppliers are large global corporations Internal economies of scale and scope, in product development, production and marketing remain important Secondly, although the supply chain is not closed to new suppliers, the emphasis is on stable, bilateral and long-term working relations with a relatively limited number of suppliers Finally, although the Lean Supply model diverges somewhat from that of the prototypical core network as regards technology development, the model does involve a lead firm that co-ordinates the network

Figure 2 1 Degrees of organisational integration



Source adapted from Langlois and Robertson (1995) and Hayter (1997)

2 4 New High Volume Production and Regional Development

This section deals with the existing theoretical and empirical insights regarding the implications of NHVP approaches for the regional development effects of MNE subsidiaries, in particular in non-core regions Although there is an overlap, it is possible to distinguish 'direct and 'indirect' regional development effects of MNE subsidiaries (Young et al , 1994) The direct effects mainly concern changes in the employment structure/conditions, functional upgrading of operations and balance of payment effects The indirect effects mainly concern the impact on suppliers, customers, competitors and firms that produce complementary goods In line with the theme of the dissertation, this section emphasises the indirect effects, notably the backward linkage effects However, some attention is given to the direct effects, in particular to the issue of functional upgrading, because of its implications for possible indirect development effects

The following two sub-sections first provide an overview of the diverging theoretical ideas and empirical evidence regarding the direct and indirect effects of NHVP The next three sub-sections look in more detail into the logic of the arguments for the suggested indirect development effects

Few regional development studies make a distinction between NHVP and other forms of flexible production For this reason, this section presents material on sectors and companies that are generally associated with NHVP, i e the automobile, consumer electronics and computer industries, and Japanese companies (e g , Lillrank, 1995, Sayer, 1986) Furthermore, given the research context of the dissertation, the bulk of empirical material presented concerns peripheral and semi-peripheral regions in Europe

2 4 1 Consequences for Regional Development in Non-core Regions Direct Effects

The widespread adoption of NHVP approaches might be expected to enhance the development prospects of peripheral and semi-peripheral regions because of the potential for functional upgrading of the subsidiaries of multinational enterprises and because of changes in the labour process and industrial relations practices, what Hudson (1994, 1997b) calls new capital-labour relations This section largely focuses on the issue of functional upgrading that, as will become apparent later, has important implications for the indirect development effects [9]

As regards changes in the labour process and industrial relations practices, Kenny and Florida (1992, 1988), portray a positive picture of better quality, empowering and enriching jobs for workers producing high quality products Increased functional flexibility, technology intensity, in combination with such principles as kaizen and learning-by-doing (Pine, 1993, Sayer, 1986), require relatively knowledgeable, multi-

[9] Capital-labour relations might indirectly impact on the linkage effects as well In relation to this, Sayer (1986, 1989) and Hudson (1997b 1997c) link the perceived efforts of NHVP companies to homogenise

skilled workers Workers will perform a wider range of tasks involving a fuller use of both intellectual and physical capabilities (Kenney and Florida, 1992) Companies will need to invest heavily in worker skills and training The relative size of the indirect labour force in manufacturing, or the 'internal tertiary sector' will grow This industrial tertiary sector is a high skill and high productivity sector in which nearly one employee in two is an executive (Veltz, 1991) Fordist coercion and hierarchical control of the labour process is replaced by flattened organisation structures, teamwork, responsible autonomy, consultation and co-operation (Sayer, 1986) Proponents of such a positive scenario believe that the training efforts and the changing occupational profile will lead to a transfer of knowledge, skills and working practices into the labour market of peripheral regions

On the other hand critics stress the continuities with Fordism and contend that the impact on regional development will be largely negative (Harrison, 1994, Hudson, 1994, Hudson, 1997c, Tomaney, 1994) Functional flexibility and multi-tasking are not believed to involve multi-skilling (Hudson, 1997b) The increased training intensity is believed to focus mainly on behavioural and social skills and less on technical skills According to Hudson (1997b) the jobs within NHVP companies are actually worse than the jobs in the classical Mass Production plants The jobs have become more intense and increasingly stressful Employment security will be enjoyed by only a small minority of core workers A large group of peripheral workers, the contingent workforce, will have to accept involuntary part-time and low-wage work – 'the dark side of flexible production' (Harrison, 1994)

As regards the issue of functional upgrading, the system of multiregional production (Womack et al, 1990) involves the creation of 'top-to-bottom', 'paper-concept-to-finished-product', manufacturing systems in each of the main markets of the world, North America, Europe and East Asia Apart from final assembly, textbook NHVP-subsidiaries will incorporate manufacturing, local-for-local R&D, technology support, sales, after-

workforces with an increasing social and spatial division of labour This will have implications for local linkage effects sales, distribution and administrative functions This suggests a serious functional upgrading of subsidiary roles compared to the 'rationalised manufacturer' and the 'miniature replica' of the Mass Production system

However, critics stress the point that NHVP organisations need to retain a certain level of co-ordination and centralisation Strategic decision-making regarding investments, production processes and product mix, is believed to remain strongly centralised in the home countries of MNEs (Hudson, 1994) The need for centralisation is believed to have a particularly strong bearing on the R&D function (Hudson, 1994, Young et al , 1994)

Furthermore, a strategy of 'multi-regional production' and the creation of 'paper concept to finished product' manufacturing systems, does not necessarily involve MNEs co-locating all functions in the same peripheral region, as is often implicitly assumed As Dicken *et al* (1994) point out, to the MNE, 'local' may well mean 'national' or 'regional' in the broader supranational sense and the dispersal of high level functions might remain highly selective geographically The greater 'local' integration of functions in each of the triad regions, might well take place on a continental 'basis' (Dicken et al , 1994, Hudson, 1995), with new high volume assembly operations located in the continental periphery and related R&D and headquarter functions located in the core – "a spatial division of labour within a large scale agglomeration" (Dicken, 1997, p 84)

Empirical evidence provides support for both sides Thus, in the context of Wales, case studies suggest increased autonomy and technological capacity amongst subsidiaries of Japanese companies (Price, Cooke, and Morgan, 1994, quoted in Phelps, 1997) Again in the context of Wales, a survey of 25 subsidiaries of Japanese firms, mainly involved in the production of consumer electronics, shows that more than half of the plants are participating in R&D and nearly half of the plants have production processes which extend far beyond the assembly stage, into genuine manufacturing (Morris, Munday, and Wilkinson, 1993, Munday, Morris, and Wilkinson, 1995) Milne (1990) surveyed 16 mainly Japanese or Korean consumer electronics plants located in the UK and found that all have some in-house design capability and, again, a number of plants were involved in component production as well as assembly Many of these plants were located in peripheral regions A more general study of high-profile foreign investment projects in various EU regions (Amin et al , 1994, Amin and Tomaney, 1995) shows that 'flagship' plants in semi-peripheral regions such as Ireland and Scotland were making gains in both the range of functions, including R&D, and in levels of management autonomy Significantly, the majority of plants had been awarded continental or world product mandates

However, the level of functional upgrading and autonomy remains limited Thus, Milne (1990) mentions that few of the 16 interviewed consumer electronics firms play a major role in the development of product technologies Most operations at best incorporate a small engineering department that can deal with 'minor cosmetic changes' to the final product (Milne, 1990) Only one company had full in-house development capability Similarly, the survey of 25 subsidiaries of Japanese companies located in Wales found that operations had a strong operational nature with only few instances of 'pure research' activities Furthermore, in relation to head-office functions and autonomy levels, in the great majority of cases the reporting linkages were centred on Japan as opposed to a UK or European head office (Morris et al , 1993, Munday et al , 1995) Again, in relation to Wales, Phelps (1997) mentions that Japanese firms continue to be truncated in some respects Similar findings were reported in relation to western car manufacturing plants in Eastern Germany (Grabher, 1994) Even in the case of 'flagship' investment projects, Amin et al (1994) report limited upgrading in less favoured regions These projects had a constrained range of management functions and most plants lacked marketing and sales departments Investments in the electronics sector, a sector often associated with NHVP approaches, were characterised by a limited range of corporate functions, constrained management autonomy and low levels of R&D

There is some evidence for a continental spatial division of labour Thus, the Japanese car industry in Europe, although integrated on a European scale, shows a clear spatial division of labour along functional lines Vehicle assembly and component plants have generally been located in peripheral regions while regional headquarter, design and marketing functions have been attracted to the core industrial heartland (Bordenave and Lung, 1996) Likewise, Pike (1998) shows that car plants in a UK industrial restructuring region retain a 'follower' role compared to 'lead' sites located in a core European region The 'follower' plants in the UK restructuring region remain reliant on centralised corporate functions for production engineering, purchasing, and product and process R&D Some upgrading has taken place with the engineering liaison functions' involvement in debugging, incremental product and process change and input into new model design to secure 'manufacturability' However, these activities are clearly focussed towards and in support of a centralised R&D function located at the 'lead' sites Phelps (1997) and Morris et al (1993) find that Japanese firms with plants in Wales are locating centres for advanced research and other higher value-added investments in core European regions

2 4 2 Consequences for Regional Development in Non-Core Regions Indirect Effects

It has been proposed that the adoption of NHVP approaches will have positive implications for regional development of non-core regions because of greater indirect effects, particularly production linkage effects The idea is that new supply chain management practices will increase the proportion of material inputs sourced from the 'regional' economy (Estall, 1985, Kenney and Florida, 1992, Mair et al , 1988) and thus increase the multiplier effect This, in turn, might engender a process of further clustering leading to "clusters of NHVP" (Hudson, 1997c) Furthermore, it has been suggested that the quality of the new supply chain relations will have positive dynamic effects on regional industrial capability and competitiveness, particularly in the context of peripheral and semi-peripheral regions (Munday et al , 1995) Compared to the traditional Fordist system, suppliers are accorded increased technical roles and supply-relationships are long-term and co-operative rather than adversarial The closer contact between customer and supplier will increase the demonstration effect of the core companies, leading to a general upgrading of the local supplier base, increased technological spin-offs and new firm formation This section focuses on the first idea, that new supply chain practices will lead to an increase in the proportion of inputs sourced from the local or regional economy

As discussed in section 2 2 4, the idea that NHVP approaches will lead to an increase in local production linkages is generally based on a relatively straightforward buyer-supplier spatial proximity argument The argument generally involves two buyer-supplier proximity drivers efficient product flow or logistical efficiency and efficient formal technical information exchange in the context of increased inter-firm functional integration (Martinelli and Schoenberger, 1991, Schamp, 1991, Estall, 1985, Hudson, 1997c, Kenney and Florida, 1992, Lubben, 1988, Mair et al , 1988, Reid, 1995, Schoenberger,–1997)' The argument generally does not involve socio-cultural and institutional issues although these might well play a role (Cooke and Morgan, 1998)

Existing empirical evidence regarding the extent of local linkages formation in sectors and companies that are generally associated with NHVP appear contradictory The positive expectations have been supported by a limited number of case-studies and surveys In the context of the US, Estall (1985), Sayer (1986), Mair, Florida and Kenney (Kenney and Florida, 1992, Mair et al , 1988) and Reid (1995) all report on high levels of local sourcing by Japanese transplants and selected, JIT-adopting, electronics and computer hardware plants On the other hand, Glasmeier and McCluskey (1987), studying the spatial configuration of the U S auto parts industry, identify a continuous trend of relocation to peripheral regions by producers of standardized parts

In the context of peripheral regions in Europe, several authors report encouraging local linkage levels among companies generally associated with NHVP In the context of Wales, although the first case-studies of Japanese MNEs found limited backward linkages (Morris, 1989), subsequent studies showed that Japanese plants in various industries were increasing their linkages with the local economy, a process that, according to the proponents, was already instigating some clustering tendencies (Cooke, 1995, Morris, 1992b, Morris et al , 1993, Munday et al , 1995) One oft-cited case was Sony in Wales, aiming for an 80 per cent local content level (Morgan, 1991, Morris, 1992a) Phelps (1997) found that Japanese subsidiaries sourced on average 18 per cent (by value) of their material inputs from Wales, 4 and 5 4 percentage points more than EU and US subsidiaries respectively In the context of the North-East of England, limited increases in local backward linkages have been reported among proactive subsidiaries in the automotive sector (Jones and North, 1991, Morris, 1992b, Phelps, 1993b, Sadler, 1997) and electrical engineering sector (Phelps, 1993b) In the context of the Northern Region of England, longer established companies in the car and car parts sector significantly increased the levels of local sourcing (Phelps, 1993a) Finally, in the context of Scotland, McCann (1998, 1996) found a positive relation between levels of local sourcing and JIT strategy in the MNE-dominated electronics industry The local input expenditure levels in the Scottish electronics industry had increased from 15 per cent in 1997 to 19 per cent in 1990

These positive reports should be interpreted with care The levels of local sourcing remain limited and other studies have been less conclusive Thus, in the context of Wales, although Japanese MNEs are characterised by higher local content levels than MNEs from Europe or the USA, local sourcing by Japanese companies remains at low levels (Morris et al , 1993, Munday et al , 1995) Similarly, proactive subsidiaries in the North-East of England had only slightly increased their local linkages (Phelps, 1993b) In the Northern Region of England as a whole, Phelps found that local sourcing by longer established plants in the electrical and electronic engineering sector had actually decreased (Phelps, 1993a) Pike (1998) reports a very limited supply base around two automotive plants in the UK Turok (1993, 1997) shows that the local sourcing levels of the Scottish electronics industry remain low at 12 per cent, while the subsidiaries of MNEs in the electronics industry, including subsidiaries of Japanese companies, have even lower levels of local sourcing Clarke and Beaney (1993), in yet another study of the Scottish electronics industry, found some strengthening of the supplier base, however the local content levels remained unchanged Finally, in the context of East Germany, most studies report some co-location around car plants However, the number of suppliers that are co-located remains limited and is an insignificant part of the total supplier base (Bordenave and Lung, 1996, Hudson, 1997a, Schamp, 1991) Furthermore, the majority of studies found that local linkages generally involve items with a low technology content (Clarke and Beany, 1993, Morris et al , 1993, Munday et al , 1995, Phelps, 1993a, Phelps, 1993b, Pike, 1998, Turok, 1993, Turok, 1997), raising questions regarding the contribution of the linkage formation to dynamic regional development

Part of the divergence in the conclusions regarding the extent of local linkage formation can be accounted for by a number of definitional and methodological issues First there is the issue of geographical scale The conclusions regarding linkage effects obviously depend on how one defines 'local' In the studies cited above, local is generally interpreted as the direct locality or region, including entities such as Wales or Scotland in the UK context In the context of the US, the positive accounts employ relatively large geographical demarcations Thus Mair et al (1988) report a concentration of Japanese assembly transplants in the 'Transplant Corridor', a region stretching over 800 miles, from southern Ontario south to Tennessee The conclusion of JIT-related supplier co-location is based on the finding that individual assemblers have about a dozen of their suppliers located within a 100 mile radius, although many suppliers are actually located further from their customer As Morris (1992b) points out, the focus of the Honda agglomeration in Ohio is 200 by 200 miles Such an area would include a large part of Great Britain (for a similar argument see Jones and North, 1991)

Interestingly, many of the above mentioned UK based studies, reporting low levels of local or regional linkages, found relatively high UK-content levels (Jones and North, 1991, Phelps, 1993a, Turok, 1997) On an even more extensive scale, a number of studies report on the high EC-content of subsidiaries of Japanese MNEs (Jones and North, 1991, Munday et al , 1995) [10] It is with this in mind that Morris asks "what scale is an agglomeration?" (Morris, 1992b, p 76) In principle, spatial agglomeration is a concept that can be applied at different geographical scales, including at the scale of the global triad (Dicken, 1997)

[10] Similarly, in the context of the USA, the backward linkage effects of Japanese subsidiaries are very low at the local level but very high at the State level (Mair, 1993, Mair et al , 1988)

Another issue that might account for part of the divergence in findings is related to research methodology Most studies mentioned above do not research the link between the proximity drivers and the spatial configuration of supply linkages in a direct manner and several commentators point to the problem of causality, inferred in these studies (Ettlinger, 1992, Hamilton, 1995, Hudson, 1994) Several other factors might instigate supplier-assembler co-location For example, in relation to the European automobile industry, Bordenhave and Lung (1996) point out that differential employment relationships, wage costs and public assistance might lead to the relocation of both assembly and component companies from core to peripheral regions Others have pointed to the EC local-content regulations as factors underlying the investments by Japanese component suppliers in Europe (Hepworth, 1989, Jones and North, 1991, Morris, 1989) An even greater error occurs when a spatial cluster of assemblers and suppliers is attributed to one of the buyer-supplier proximity drivers, while in reality the companies have no, or very few links to each other (Mair, 1993)

However, putting aside the above definitional and methodological issues, the explanation for the divergence in the findings regarding local linkage formation will for a large part lie in the fact that the various drivers for proximity do not necessarily lead to buyer-supplier proximity and that the spatial outcome is highly dependent on a range of component and industry characteristics and contextual conditions In general, the theoretical arguments concerning the spatial implications of new supply strategies suffer from a lack of conceptualisation (Mair, 1992) The next two sections examine the logic related to the two buyer-supplier proximity drivers most often put forward in relation to NHVP industries efficient formal technical information exchange and logistical efficiency

2 4 3 Supplier Proximity for Efficient Formal Technical Information Exchange

As outlined in section 2 3 2, partnership-based NHVP models are characterised by strong customer-supplier integration, involving a great deal of dyadic information exchange

This is one aspect of the growing information intensity of manufacturing that can be postulated to have implications for the spatial configuration of manufacturing industry (Hepworth, 1989) In spite of space-shrinking IT developments, some types of information exchange still require large amounts of face-to-face contact The argument for spatial proximity is based on the idea that, although face-to-face communication does not necessarily require proximity, proximity does enhance speed and efficiency in communication by reducing the travel time

The argument does not involve all information exchange Based on the nature of the information content, one can distinguish three types of information in a supply relation commercial, administrative and technical (Gadde and Hakansson, 1993) As regards the commercial and administrative content, the partnership model involves a constant formal communication of prices, discounts, times, volumes, means of delivery and payment, stock data, current and forecast demand Although, this exchange involves a strong integration of the partners' purchasing, sales, materials management, logistics and accounts functions (Hepworth, 1989), it is not regarded as a driver for customer-supplier proximity in the NHVP literature

The literature on the spatial implications of partnership-based supply relations focuses, nearly exclusively, on the communication of technical information (for example, Bordenave and Lung, 1996, Glasmeier and McCluskey, 1987, Lubben, 1988, McKinnon, 1997, Pike, 1998, Reid, 1995, Womack et al , 1990) The idea is that the customers' increasing reliance on their suppliers for innovation requires a strong integration of engineering and production functions of both partners and an increase in the formal exchange of technical information – both in the early stages of product and process development, involving co-development and simultaneous engineering, and the later stages, involving ongoing technical co-ordination Because of the fact that such information is often ambiguous and subject to refinement, a large part of the exchange is believed to require face-to-face interaction between engineers (Reid, 1995, Schoenberger, 1997)

Some commentators argue that innovations in communication technology have reduced the need for face-to-face contact, even in the context of detailed technical design issues (Gertler, 1988, Hepworth, 1989, McKinnon, 1997) Arita and McCann's (2000) study of US semiconductor industry suggests that the need for proximity depends on the intensity of the formal information exchange, intensity defined as the detail and sensitivity of the information involved For their study they devised a classification of the technological content of the partnership, based on the intensity of information exchange involved At one end, 'joint R&D and joint-development of new technology' was expected to promote the most intensive interactions of knowledge exchange, requiring high levels of face-to-face contact between partners At the other end, the category 'manufacturing' (described as subcontracting of mass produced activities such as original equipment manufacturing, second sourcing, and fabrication agreements) was believed to involve far less intensive interaction regarding technical information, and therefore to require low levels of face-to-face contact

Their findings show that formal technical information exchange is a driver for the reduction in the linkage distance in case of higher-order alliances only However, even in these alliances, the critical spatial extent over which the information-localisation effect is found to operate is within one day's return journey by air – much less localised than generally assumed Formal exchange of technical information did not drive co-location of partners involved in lower-order alliances, not even at the scale of the USA in total Furthermore, it is important to mention that the findings pertain to *small* US semiconductor firms only Information exchange is probably an even less spatially restrictive issue for larger firms, particularly for MNEs (McKinnon, 1997) In relation to this McCann and Fingleton found that firms in the Scottish electronics industry, made-up mainly of subsidiaries of large MNEs, "were already used to co-ordinating long-term supplier-customer relationships which continuously involved the exchange of detailed and complex information on a global basis" (1996, p 500)

For alliances involving less intensive technical information exchange 'organisational proximity' might suffice This might involve providing customers with the experience of a local engineering and manufacturing experience, without actually co-locating facilities (McKinnon, 1997) This might take the form of local agents or small local support units For example, in more recent supply models, such as JIT II, suppliers station a resident planner-engineer, or 'in-plant', at customers' facilities (Pragman, 1996)

Another issues relates to the level of standardisation of the material inputs involved The intensity of technical information exchange varies from one material input to another Highly standardised components, involving minimal design changes might require less face-to-face contact than highly customised components, undergoing frequent design or specification modifications According to some commentators, supplier-proximity might therefore be less important in the case of highly standardised material inputs (Bordenave and Lung, 1996, Glasmeier and McCluskey, 1987, Hirakubo and Kublin, 1998, Reid, 1995)

Obviously the formal information exchange/ spatial proximity argument is only relevant to overseas operations of NHVP companies, when these operations are actually involved in technical information exchange with suppliers As discussed, the textbook post-national company and the system of multiregional production involves the establishment of integrated operations in the three main markets of the world, incorporating local-for-local R&D functions As in the home country, product development and assembly in overseas operations will be supported by the local engineering departments of the suppliers Thus, supported by the findings of Womack (1990), efficiency in the exchange of technical information is believed to be a driver for assembler-supplier proximity in the context of overseas operations as well

However, as mentioned in section 2 4 1, a number of commentators point out that the corporate organisation structure associated with textbook NHVP, i e a system of multiregional production characterised by a 'top-to-bottom', 'paper-concept-to-finished-product', manufacturing systems in each of the three main markets of the world is seldom fully born out The requirement of NHVP organisations to retain a certain level of co-ordination and centralisation is believed to pertain in particular to the R&D function, which remains strongly centralised in the MNEs' home country Alternatively, because of the specific labour requirements involved, R&D functions are located in core European regions Most operations located in non-core regions at best incorporate a small engineering department mainly involved in day-to-day production and *quality control* management Such situations would render technical information exchange irrelevant as a driver for a reduction in the linkage distance in the context of overseas operations located in non-core regions

2 4 4 Supplier Proximity for Logistical Efficiency

As mentioned in section 2 3 2, one of the central components of all NHVP approaches is JIT supply JIT supply is often presented as the optimal logistics system, characterised by the elimination of buffer inventories, a *kan-ban* delivery system that delivers inputs on a daily basis directly to the production line and near synchronous production This system is believed to lead to close buyer-supplier proximity (Estall, 1985, Kenney and Florida, 1992, Mair, 1992, Mair et al, 1988, Sayer, 1986, Schoenberger, 1997) – suggested maximum workable distances range from 30 miles to 200 miles, depending on the quality of the regional physical infrastructure – and normally receives titles such as 'true JIT' (Morris, 1989, Morris, 1992b), 'full JIT' (Mair, 1992), or 'pure JIT' (Fawcett and Birou, 1992)

However, true JIT supply should really be interpreted as one extreme outcome in a spectrum of possible optimal outcomes based on modern comprehensive logistics management principles, which take account of the interrelationships between inventory costs, transportation costs, shipment frequencies, the opportunity costs of quality associated with inventory and variation in labour costs between regions A number of component characteristics and contextual conditions can lead to supply systems involving less frequent delivery patterns, greater shipment sizes, higher buffer levels and greater buyer-supplier distance The explanation requires a closer look at the logic behind JIT supply

Until the mid-1960s, the typical manufacturing company managed all inventories with 'order-point' systems based on the principle of replenishment The individual order quantities, or lot sizes, were typically based on a traditional economic order quantity (EOQ) formulation (Christopher, 1992, McCann, 1998, McCann and Fingleton, 1996, Schroeder, 1993) The EOQ model is based on the idea that it is possible to calculate 'optimum' order quantities/ shipment frequencies, involving minimal 'total logistics costs' (TLCs) These TLCs are the sum of the ordering/set-up costs, the costs of holding inventories and the costs of transporting goods The ordering/set-up costs include the administration costs involved in organising an individual purchase, plus the labour costs involved in machinery set-up The EOQ is derived by balancing these cost components [11] This replenishment system tends to involve relatively high levels of buffer inventory and safety stock and one of the main problems is that it often leads to high levels of excess inventory, particularly in cases of 'lumpy' demand patterns

In contrast, JIT is a requirements-driven system Orders are based on requirement forecasts that are regularly updated In contrast to a replenishment system, no orders are placed in periods of slack demand The mam objective is to minimise component inventory levels The modern comprehensive logistics management principles that underlie JIT, incorporate new insights regarding the cost of holding inventories According to McCann (1998), compared to the traditional models, two extra cost factors are considered space costs and total quality costs (TQCs)

The modern comprehensive logistics management principles involve a more inclusive interpretation of what constitutes TLCs, notably the recognition that, next to interest

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[11] The traditional formulation of the EOQ is expressed as $Q^* = \sqrt{\frac{2mS}{Ic}}$,where Q^* is the economic order quantity, m is the quantity of input per time period, S is the ordering/set-up costs of conducting each individual shipment, I is the rate of interest and c is the source price per unit of input (McCann, 1998) With his broader logistics costs model McCann (1996, 1998) shows how total input logistics costs are generally a positive function of transport costs and, thus, of distance Correspondingly, the EOQ is dependent on transport costs and distance Integration of this idea, and assuming shipment economies of

costs, space costs represent a significant part of the inventory holding costs, one of the components of TLCs The space costs of inventory are the space and space handling costs of storage and warehouse space, comprising the land costs and the labour costs involved in inventory handling operations These cost components have not been included in traditional Western purchasing techniques, which, as a consequence, underestimate the real costs of holding inventories

Another aspect of the comprehensive logistics management principles that underlie JIT concerns the recognition of the importance of quality-competition and, therefore, the significance of the quality costs The quality costs are the combined costs of lost market share due to poor quality and reliability of the final product and the costs of final quality control administration, which are the costs of the expediting of materials, the costs of lost orders, back-orders, scrap and rejects The greater the average volume of inventory held, the greater is the risk that faults in individual components will go undetected during the production process – the greater the quality costs

Thus, the traditional logistics models underestimate the real costs of holding inventories and, compared to these traditional models, the comprehensive logistics management principles hold a greater incentive to minimise the average volume of inventories This volume of inventories can be reduced by reducing the shipment size and increasing the shipment frequency In modern quality-competitive markets the significance of TQCs and space costs may be so great that the EOQ tends towards zero, i e lot sizes of one [12] However, if shipment sizes go down, and shipment frequencies go up, the transport cost and ordering/set-up cost components of the TLCs will rise There are two ways this can be prevented First, firms can work towards a reduction of the ordering/set-up costs of

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scale, leads to the following formulation for the EOQ $Q_i^* = \sqrt{\dfrac{2m(S + ad_i)}{Ic}}$, where a is movement costs per mile and d is delivery distance

[12] Taking account of the space costs and TQC, the new formulation of the EOQ becomes $Q_i^* = \sqrt{\dfrac{2m(S + ad_i)}{q + s + Ic_i}}$, where s is the logistics space cost coefficient and q expresses the impact of the TQC Thus the higher the value of s and q the closer the EOQ will be to zero (McCann, 1998)

conducting each individual shipment, for example by streamlining the order entry system Secondly, and more importantly for the present discussion, firms can attempt to reduce the input delivery distance This is the basic logic behind the JIT-proximity argument[13] (for a similar argument, see Mair, 1992)

The idea that there are forces that drive customer-suppher proximity is obviously not new Even the traditional logistics models and the traditional way of calculating the EOQ could lead to a situation where the transport costs and the interest costs of holding inventories would drive customer-supplier co-location In fact, one could consider buyer-supplier co-location as the 'normal' situation It is only because of issues such as differences in labour costs between locations and the existence of economies of scale in component production, and a whole range of reasons related to history, the technological capabilities of a region and locational inertia, that customers use suppliers located in other regions The difference with the comprehensive logistics management principles that underlie JIT is that the forces tending towards buyer-supplier proximity are stronger due to the appreciation of the role of space costs and TQCs

However, this does not mean that adoption of the comprehensive logistics management principles will necessarily involve very high shipment frequencies, very small buffer inventory levels and buyer-supplier co-location Paraphrasing Christopher (1992), companies still have to make a range of 'trade-offs' in working towards the improvement of total supply chain cost effectiveness – the ultimate goal of any logistics system This is well captured by the following quote of the director of purchasing and logistics at Bose's speaker plant in the USA "While Bose is committed to the principles of JIT inventories, [Bose] wants to make sure individual decisions make financial good sense We are looking for the best cost That means constantly balancing factors such as the value of the goods, how quickly they are needed, and shipping costs" (Bradley, 1989) The

[13] The actual argument, as laid out by McCann (1998, 1996) is slightly more complex, taking account of the fact that in many firms quality costs are primarily opportunity costs of lost sales that do not show up in any accounts McCann's more complex argument shows that the proximity argument holds even within the visible and measurable cost constraints set by traditional accounting conventions

specifics of the logistical arrangements and the effects on linkage distance are highly dependent on a range of component characteristics and contextual conditions

One very important factor concerns the regional labour cost differences, as reflected in the price of components The optimisation principle means that firms will balance the logistical efficiencies gained by proximate location with the savings due to the lower input price More distant suppliers may be able to compete with lower prices because of cheaper labour costs If these production cost advantages are greater than the efficiencies gained by co-location, then a firm might operate JIT supply over larger distances (McCann, 1998) or operate logistics systems that diverge substantially from the prototypical true JIT system

Another issue concerns the minimum efficient scale of component production The comprehensive logistics management principles will only lead to buyer-supplier co-location if the demand of individual customers is sufficient to allow for production at minimum efficient scale Scale issues often mean that component manufacturers need to supply several customers which can mean that suppliers are located at considerable distances from some of their customers (Bordenave and Lung, 1996, Jones and North, 1991, McKinnon, 1997, Milne, 1990, Morris, 1992b, Schamp, 1991)

Another oft-cited issue relates to the value and the bulk or weight of individual components However, the issue is not, as suggested by more traditional location models, that proximity is of less importance for inputs with a high value-to-weight ratio because high value components are simply able to bear higher transportation costs (Lever, 1974, O'Farrell and O'Loghhn, 1980) As McCann (1998) points out, in competitive industries transport costs can represent a significant competitive cost component irrespective of the value of the product

In fact, the comprehensive logistics management principles that underlie JIT hold that the incentive for increasing shipment frequency, decreasing order size and decreasing linkage distance will be greater for high value components than for low value components

(Christopher, 1992), *ceteris paribus*, since components with a high value will incur much higher interest and insurance costs The principles also hold that the incentives for increasing shipment frequency and decreasing linkage distance are greater for physically bulky and heavy components than for small and light components, *ceteris paribus* (Lubben, 1988, McKinnon, 1997), since physically bulky components will incur higher space costs while the transport costs are higher for both physically bulky and heavy components Very cheap and physically small inputs, such as bolts, will incur very limited interest costs and require limited warehousing space In those instances, a decrease in the shipment frequency, increase in the order size and increase in the linkage distance will have a more limited impact on the inventory costs In other words the forces tending towards co-location are weaker and relatively small wage differences and savings related to the economies of scale in the production of components might more easily bring about an increase in the linkage distance

Yet another issue concerns the variety of options per component category (Bordenave and Lung, 1996, Christopher, 1992) The incentives for increasing the shipment frequency and proximity will be stronger for component categories involving a high variety of options (e g different colours, styles or shapes) than for more standardised component categories This is because the greater the variety of options within a component category, the higher the inventory holding costs involved in stockpiling a certain level of finished components in all possible permutations (Christopher, 1992, Van Hoek, 1998), particularly in situations of highly unpredictable demand Therefore, the greater the variety of options, the greater the incentive to delay the final assembly of component materials into finished components The greater the delay in final assembly, the greater the shipment frequency, the greater the driver for buyer-supplier proximity

A final issue concerns the sophistication of the component technology relative to industrial technical capabilities of a locality The adoption of the comprehensive logistics management principles that underlie JIT will not lead to local component sourcing when the required technology is simply beyond the limited industrial capabilities of a region

(McCann and Fingleton, 1996, Morris, 1992a, Phelps, 1993a, Phelps, 1993b, Reid, 1995)

All these component characteristics and contextual conditions mean that the adoption of comprehensive logistics management principles underlying JIT can have a variety of outcomes, involving both local and overseas sources and a combination of delivery methods (Lubben, 1988) At one end of the spectrum, the pipeline of some components will be organised along the lines of a true JIT system, characterised by extremely low buffer inventory levels[14], a *kan-ban* delivery system that delivers outputs on a daily basis[15] directly to the production lines and suppliers located in close proximity to the customer

According to some, true JIT supply no longer requires customer supplier proximity The argument is that technological developments in transport and logistics render the proximity argument obsolete for all but a few exceptional situations (Milne, 1990) The point is made that it is not the distance but the travel time which is important (Lamming, 1993) and that faster, more reliable and cheaper transport has extended the spatial limits within which a true JIT system can operate It is technically possible to receive daily deliveries over considerable distances Furthermore, the costs of rail, road and air transport have come down, partly as a result of inter-modal transportation linkages, developed to facilitate JIT processes over large distances (Ettlinger, 1992) As a result, the argument goes, transport costs are making up a decreasing proportion of total industrial costs and, consequently, the drive towards proximity is reduced Indeed, there are reports of companies sourcing certain inputs on a true JIT basis from other countries or even other continents (Clarke and Beany, 1993, Glasmeier and McCluskey, 1987, Lamming, 1993, McCann, 1998, Milne, 1990)

[14] Although, the system will always involve certain work-in-process inventories to 'time the system system' and to compensate for some production and transportation time (Lubben, 1988)

[15] The criteria are arbitrary Some authors reserve the term 'true JIT' for cases involving multiple deliveries a day (Morris, 1989, Morris, 1992b)

However, these examples remain the exception rather than the rule. Under true JIT, in most cases transport costs continue to have some impact on buyer-supplier distance. Frequency, distance, speed, reliability and the costs of transport remain interrelated issues that have to be traded-off (McKinnon, 1997). Important in this is that transit time variability tends to increase with the number of transport modes used and number of international frontiers to be crossed (McKinnon, 1997). Thus, while it might be technically possible to organise true JIT supply systems spanning large geographical areas, it might not be cost efficient to do so. In general, the possible scale of operation for true JIT supply appears to have extended from the very local to an area with a 150 to 200 miles radius, which in the context of the European space economy often means the national scale (Milne, 1990), although unfavourable infrastructure conditions might require more proximate location (Mair, 1993).

Alternatively, the adoption of comprehensive logistics management principles might lead to a "JIT-type" supply system (Crowley, 1996) involving slightly less frequent shipments and slightly higher buffer inventories and suppliers at greater distances. In such instances, "the meaning of JIT delivery starts to change" (Lubben, 1988, p. 192). At the other end of the spectrum of outcomes, the pipelines of components might involve yet less frequent shipments, higher (but tightly managed) buffer inventory levels and suppliers located at considerable distances.

The practicality of such systems has increased because of innovations in transport and logistics. Thus, a survey among American manufacturing firms found that many are now extensively using airfreight, inter-modal transport and door-to-door, less-than-truckload, logistics services in order to reduce lead-time, pipeline inventories and buffer inventories and increase shipment frequency and on-time delivery (Fawcett and Birou, 1992). This development occurred as firms have "moved towards total cost analysis and … recognised the importance of time-based-competition" (p. 12). The systems include inter-continental supplies (Far East–North America) delivered, with a high degree of on-time performance, in two to three days by using air-freight. Inter-modal shipment involving ocean-freight can be as fast as 12–14 days. Although only four per cent of the respondents receive their internationally sourced items on a daily basis, almost one quarter receive these inputs on a weekly basis with a further 20 per cent receiving bi-weekly deliveries This means pipeline inventories of less than five days for 17 per cent of the respondents with another 20 percent of the respondents reporting levels of six–ten days The new logistical solutions have presented "an interface between global [read from abroad] and JIT sourcing" which allows firms to "globally source materials on a JIT basis" (Fawcett and Birou, 1992, p 6-7)

Supply chains involving suppliers at great distances normally hold a level of intermediate inventory between supplier and customer, if only to buffer against extended transit lead times (Christopher, 1992) The actual ownership and physical location of these inbound logistics buffers may vary The arrangement may be that the customer owns all buffer inventories A customer might choose to stock a few days worth or a weeks worth of supply 'on-the-line' and hold title to these inventories (Lubben, 1988) In other cases, the buffers might be kept in on-site warehouses (Jones and North, 1991, Mair, 1992) or in off-site warehouses, either owned by the customer or by a third party Off-site warehouses might be used in case of space shortage, or in order to relieve traffic pressure and retain efficiency at reception (Lubben, 1988, McKinnon, 1997)

Alternatively, the buffer inventories can be owned by the supplier and, here too, the actual physical location can vary Thus, suppliers can hold buffer stocks at the assembly line of the customer and goods do not change title until the moment of use A popular approach in this regard is the 'bread man' system where the supplier takes responsibility for maintaining the line inventories at an agreed level, based on 'blanket purchase orders' (Lubben, 1988) Other arrangements involve suppliers keeping buffers in a customer's on-site warehouse, possibly operated by the vendor (Pragman, 1996) In yet other cases buffer inventories are kept in closely situated, off-site, warehouses, owned and operated by either the buyer, the supplier or a third party (Glasmeier and McCluskey, 1987, Lamming, 1993, Lubben, 1988, Pyke, 1995, Ryan, 1997, Schamp, 1991) Increasingly, both small and large companies tap into the knowledge and capabilities of international third party logistics suppliers (3PLs), as one way of dealing with the complexities of operating an efficient supply system involving overseas suppliers (Lubben, 1988) and/or to free up valuable resources

Thus, increasingly assemblers are reducing their inbound inventories to a minimum while the suppliers are requested to provide JIT deliveries from finished component inventories, stored in local warehouses These systems are often referred to as 'apparent JIT' (Lamming, 1993, Ryan, 1997) or 'pseudo JIT' (Hudson, 1994) It is often suggested that these supply systems are sub-optimal and hold no benefit for the supply chain as a whole, since the costs of inventory remain in the system (Lamming, 1993) However, the actual ownership and location of the inbound logistics buffers has no relevance from a supply chain efficiency point of view The fact that the supply system diverges from the prototypical true JIT picture does not mean that the comprehensive logistics management principles are not appreciated These supply systems can only be interpreted as sub-optimal if the size of the buffers and the use of warehouses reflect inflexibility in manufacturing and poor materials management procedures (Christopher, 1992)

2 4 5 Aspects of NHVP-Related Supply Chain Strategies Leading to an Increase in the Linkage Distance

Apart from the information exchange and logistics related drivers for buyer–supplier proximity, a number of authors argue that other aspects of NHVP-related supply chain strategies might actually lead to an increase in linkage distance and a reduction in local sourcing In this regard, Phelps (1993b) mentions, *inter alia*, the reduction of the number of suppliers per component and company-wide consolidation of purchases (see section 2 3 2)

The reduction of the number of suppliers per component will mean that an increased amount of business is placed at a sharply reduced number of significantly larger suppliers, with the required financial and productive resources According to some observers, these larger, often oligopolistic suppliers, are restructuring their global operations, more independently of individual customers' locations and the resulting spatial implication might be a regionally or globally dispersed supplier plant configuration, and a reduction in local linkages (Glasmeier and McCluskey, 1987, Hudson, 1994, Morris, 1992b, Phelps, 1993b, Schamp, 1991)

Company-wide consolidation of purchases involves centralised purchasing systems in multi-plant companies consolidating the purchases of input requirements of several plants This strategy will provide the network of plants with purchasing economies and product consistency at a continental or even world-wide basis, although transatlantic consolidation is believed to be rare (Phelps, 1993b) A number of authors suggest that this strategy might lead to a reduction in local linkages (Clarke and Beany, 1993, McCann, 1996, Morris et al , 1993, Munday et al , 1995, Phelps, 1993b, Pike, 1998) The idea is that a reduction of supplier locations will generally mean an increase in the linkage distance for most assembly plants Furthermore, centralised purchasing systems have been related to a lack of subsidiary autonomy, often perceived to lead to lower levels of local sourcing (McCann, 1996, McCann, 1997, Phelps, 1993a) However, these arguments are not always valid

Consolidation of purchases on a global basis does not necessarily mean that inputs are manufactured in one global plant Assemblers that prefer suppliers that can supply their entire network of plants might still be choosing those suppliers that can supply them from various manufacturing sites Obviously, if purchases are consolidated at one single plant located in one of the low-cost South-East Asian NICs, the linkage distance for assembly plants in Europe will increase However, in that case the increase in linkage distance for assembly plants in Europe is more related to product cost differentials than the result of a consolidation strategy As mentioned by Phelps, "the consolidation of purchases [ ] is also bound up with a deliberate strategy to find lower cost sources in less developed countries" (Phelps, 1993b, p 868)

Similarly, the arguments that relate centralised purchasing systems to low subsidiary autonomy and low levels of local sourcing, often contain huge logical jumps The underlying logic is that centralised purchasing departments are uninformed about and/or not sensitive to the requirements of and possibilities for local supply at subsidiary level A number of authors have questioned a direct relationship between levels of subsidiary autonomy and the extent of local linkages (Clarke and Beany, 1993, O'Farrell and O'Loghlin, 1980) There is no reason to believe that centralised purchasing systems will be less interested in the benefits of local sourcing for individual plants and, on the other hand, "it is quite conceivable that increased organisational autonomy for a subsidiary may lead to globalization of purchasing" (Dicken et al , 1994)

2 5 NHVP and Local Linkage Formation Four Research Patterns

The theoretical contributions of this dissertation concern mainly the extent and causes of local linkage formation associated with NHVP approaches, in non-core European regions Sections 2 4 3 and 2 4 4 showed that the effect of NHVP approaches on the location of suppliers is far from straightforward Theoretically, efficient technical information exchange and logistical efficiency can lead to buyer-supplier proximity However, the ultimate location of suppliers will depend on a great number of factors such as the intensity of technical information exchange, the value and physical characteristics of the components, the minimum efficient scale for the production of the components, regional differences in labour costs, the continuously developing level and costs of transport and communication technology, regional differences in technological capability, as well as a range of other factors that have not been specifically incorporated in the present study, such as regional differences in fiscal and financial incentives, and factors related to history and locational inertia Taking these various product, sector and contextual issues into account, one target and three rival research patterns guided the case study of linkage formation associated with NHVP approaches This section outlines these patterns The patterns are summarised in Table 2 2

Research pattern 1a significant local linkages – both comprehensive logistics management principles and technical information exchange drive proximity

In this research pattern, NHVP companies source a high proportion of their required parts and components from the regional economy Geographic proximity is driven by the requirements of both efficient technical information exchange and logistical efficiency As regards technical information exchange, local operations of NHVP companies incorporate substantial local-for-local R&D and engineering functions, involved in intensive exchange of technical information with suppliers Efficiency in essential face-to-face communication requires proximity of operations of the partners involved As regards logistical efficiency, the combination of component characteristics and contextual conditions means that true JIT supply, involving regional suppliers, is the optimal system for the majority of components

The pattern has been further operationalised as follows The majority of the main component and parts suppliers are located in relatively close proximity, at least in the same country as the customer (in the context of the present case study Ireland or Scotland) Furthermore, this proximity is not 'coincidental', rather it is based on a deliberate choice to deal with local suppliers Assembly operations involve substantial local-for-local R&D and engineering departments Staff in these departments has frequent face-to-face contact with their counterparts in the local operations of the suppliers Communication would be difficult to maintain over longer distances Inter-company product flow is characterised by shipment frequencies of at least once a day and small shipment sizes, leading to minimal buffer inventories

This pattern is presented as a rival hypothesis for several reasons As regards the requirement of efficient technical information exchange, following Hudson (1994) and Young (1994), it is postulated that the process of decentralisation of functions will be partial and that R&D in particular remains strongly centralised in the MNEs' home countries As outlined in section 2 4 1, many surveys and case-studies of sectors normally associated with NHVP, find that R&D functions of operations in European peripheral regions remain limited (Grabher, 1994, Milne, 1990, Morris et al , 1993, Pike, 1998) Apart from a few oft-cited cases, most operations in non-core regions at best incorporate a small design function that can deal with customer-specific adaptations or minor cosmetic changes to the final product (Milne, 1990, Pike, 1998) The same studies point to a 'liaison function' of local engineers with centralised R&D staff to secure manufacturability and facilitate product and process change However, this liaison takes place with centralised R&D staff – design-related interaction between local engineers and local suppliers is expected to be very limited The local engineering groups' role in issues related to quality of parts and components does involve technical information exchange with suppliers However, following Arita and McCann (2000), it is postulated that the technical information exchange involved in these issues is not intensive and requires limited face-to-face contact All this renders efficient exchange of technical information irrelevant as a driver for a reduction in the linkage distance in the context of foreign subsidiaries of MNEs located in non-core regions

Even if the European operations play a substantial role in the corporate process of technological co-ordination with suppliers, the postulation is that this will not present a strong driver for buyer-supplier co-location Taking account of the findings of Arita and McCann (2000) the belief is that technical information exchange is a driver for proximity only in case of a limited number of higher-order alliances, characterised by a high intensity of the technical information exchange Furthermore, even in these alliances Arita and McCann find that the intensive technical information exchange can be organised efficiently over a distance not exceeding one day's return journey by air The proximity effect would therefore show on a Western European scale, rather than on a national scale Finally, Arita and McCann's study and findings pertain to *small* semiconductor firms only In this thesis, based on the ideas of McCann and Fingleton (1996) and McKinnon (1997), the postulation is that intensive technical information exchange is an even less spatially restrictive issue for large globally operating MNEs involved in NHVP

As regards logistical efficiency, the contention is that NHVP companies do take account of the comprehensive logistics management principles in the management of their supply chains However, for a combination of reasons (see research scenario 2a) it is postulated that these considerations will not lead to buyer-supplier proximity on a national scale Rather, for the majority of components, global sourcing, involving managed inventory levels, will prove the optimal solution

Research pattern 1b significant local linkages – comprehensive logistics management principles drive proximity but technical information exchange does not

Here, NHVP companies source a high proportion of their required parts and components from the regional economy However proximity is driven by the requirement of logistical efficiency only The requirement of efficient technical information exchange proves not to drive customer-supplier proximity The NHVP operations in the non-core regions incorporate no significant R&D functions Local engineering groups are mainly involved in non-intensive exchange of technical information with suppliers, mainly concerning part and component quality This information exchange requires limited face-to-face contact and, therefore, does not drive customer-supplier proximity

This pattern has been operationalised as follows Like in the previous scenario, the majority of the main component suppliers are located in relatively close proximity, at least in the same country as the customer Furthermore, this proximity is not 'coincidental', rather it is based on a deliberate choice to deal with local suppliers Inter-company product flow is characterised by shipment frequencies of at least once a day and small shipment sizes, leading to minimal buffer inventories Customers' assembly operations incorporate no substantial local-for-local R&D groups Where local engineers are involved in the face-to-face exchange of technical information with local suppliers, this contact is not the real driver behind the co-location of facilities It is relatively easy to organise this exchange, in an efficient way, with suppliers located further afield

This pattern is presented as the second rival hypothesis, although it is considered more likely than scenario 1a The results of an earlier study into the locational impact of JIT linkages in the Scottish electronics industry match this pattern to an extent

> Two general results came out of the initial survey The first result was that the philosophy of JIT was being applied more or less the same everywhere in all the plants All firms were aiming to reduce the level of inventory held within the plant by requiring their suppliers to deliver goods in smaller more frequent individual shipments The second result was that not only were all firms attempting to use local suppliers wherever possible in order to produce their material inputs, but that the reason for this was primarily in order to allow frequent small-scale JIT shipments of input materials to be made, rather than due to any reasons of the necessity of geographical proximity to facilitate supplier-customer information exchange (McCann and Fingleton, 1996, pp 499-500)

For reasons outlined under pattern 1a, it is postulated that efficiency in the exchange of technical information is not a driver for customer-supplier proximity in the context of foreign subsidiaries of MNEs located in non-core regions Furthermore, the contention in this dissertation is that NHVP companies do take account of the JIT principles in the management of their supply chains However for a combination of reasons (see research scenario 2a) it is postulated that these considerations will not lead to buyer-supplier proximity on a national scale

Research pattern 2a no significant local linkages – neither comprehensive logistics management principles nor technical information exchange drive proximity, but the principles are appreciated

In this pattern NHVP companies source the vast majority of their required parts and components from global sources and the amount of linkages with the regional economy is limited Neither the requirement of efficient technical information exchange nor the requirement of logistical efficiency leads to customer-supplier proximity, not even on a national scale The NHVP operations in the non-core regions incorporate no significant

R&D functions Local engineering groups are mainly involved in non-intensive exchange of technical information with suppliers, mainly concerning part and component quality This information exchange requires limited face-to-face contact and, therefore, does not drive customer-supplier proximity As regards logistical efficiency, like under patterns 1a and 1b, NHVP companies do take account of the comprehensive logistics management principles in managing their supply chains However, these considerations do not lead to buyer-supplier proximity on a national scale Rather, global sourcing, involving managed inventory levels, is the optimal solution for the majority of components Thus, in contrast to the logistics system described under pattern 2b, this logistics system represents an optimal supply chain solution

This pattern has been further operationalised as follows The majority of the main component and part suppliers are located at a considerable distance – at least outside the country and in many cases on other continents Inbound logistics associated with these foreign sources involves certain buffer inventories, generally held in warehouses from where the production lines are supplied 'just-in-time' As such, the inbound logistics system diverges from the textbook true JIT logistics system However, the comprehensive logistics management principles are appreciated and are taken into account in the trade-off between the benefits of using local or overseas suppliers and in the organisation of logistics Average buffer inventories are prevented from rising too far above an optimal target level, by tightly managing the logistics pipeline Component supply by overseas suppliers involves high shipment frequencies and small shipment sizes In contrast to the traditional Fordist way of sourcing, which involves overseas suppliers delivering once every two or three months, this scenario involves regular on-time deliveries on a daily, weekly or bi-weekly basis (Fawcett and Birou, 1992)[16]

The actual ownership and geographical location of the inbound logistics buffers may vary and inbound logistics might well involve a combination of arrangements However,

[16] According to Fawcett and Birou (1992), even deliveries on a monthly basis can be in accordance with the comprehensive logistics management principles

suppliers that hold title to the buffers are not 'forced to eat inventories' as reported by Roper *et al* (1997) and Morris (1993), but are compensated for providing the facility

Finally, this pattern does not rule out local linkages altogether Characteristics such as high physical volume/weight, high value, great variety of options within a component category will lead to close buyer-supplier proximity in case of a minority of components Where these characteristics do lead to local sourcing, the choice for local suppliers is not driven by considerations related to efficient technical information exchange Thus, the operationalisation as regards R&D and local engineering functions is the same as under scenario 1b

This pattern represents the target hypothesis For reasons outlined under pattern 1a, it is postulated that efficiency in the exchange of technical information is not a driver for customer-supplier proximity in the context of foreign subsidiaries of MNEs located in non-core regions As regards logistical efficiency, the contention in this dissertation is that NHVP companies do take account of the JIT principles in the management of their supply chains However, it is postulated that rising differences in labour costs between regions in combination with innovations and price reductions in transport and logistics mean that for the majority of components the optimal supply chain solution does not lead to buyer-supplier proximity on a national scale Rather, in the majority of cases the optimal solution will involve suppliers located in regions with substantially lower labour costs, particularly in the Far East

Research pattern 2b no significant local linkages – neither the comprehensive logistics management principles nor technical information exchange drive proximity, and the principles are not appreciated

This pattern represents the third rival hypothesis As in research pattern 2a, in this research pattern NHVP companies source the vast majority of their required parts and components from global sources and the amount of linkages with the regional economy is limited Neither the requirement of efficient technical information exchange nor the requirement of logistical efficiency leads to customer-supplier proximity, not even on a national scale The requirement of efficient technical information exchange does not drive customer-supplier proximity, for the same reasons as outlined under research patterns 1b and 2a As regards logistical efficiency, companies do not take account of the comprehensive logistics management principles in managing their supply chains The choice between a local and an overseas source is based on a trade-off where the total logistics cost component is under-estimated The result is a sub-optimal supply chain involving mainly overseas suppliers and excessive local inbound inventories Customers' internal JIT production systems might be frequently fed with supplies stored at local warehouses But these warehouses contain sub-optimal inbound inventory levels – "a new variant of just-in-case" (Hudson, 1994, Hudson, 1997c)

This pattern has been further operationalised as follows The majority of the main component and part suppliers are located at considerable distance - at least outside the country and in many cases on other continents The logistics associated with these foreign sources involves high levels of inventories, both in the pipelines and stored in local warehouses – 'just-in-case' – although these local warehouses might well supply the production lines on a 'just-in-time' basis The inbound inventories are not tightly managed – inbound buffers amount to a couple of months' worth of supply Component supply by overseas suppliers involves infrequent shipments, i e bi-monthly or even less frequent, and large shipment sizes, so companies are able to exploit economies of scale in transport The logistics system favours cheaper transport alternatives, i e slow ocean freight The actual ownership and geographical location of the inbound logistics buffers may vary and inbound logistics might well involve a combination of arrangements The customer's wish to eliminate inventories can mean that suppliers are 'forced to eat inventories'

Table 2 2 Research patterns

Research Pattern	Operationalisation
Research Pattern 1a (rival) Significant local linkages – both comprehensive *logistics* management principles and technical information exchange drive proximity	-Customer and majority of material input suppliers located in the same country -Proximity is deliberate -Substantial local-for-local R&D and engineering departments in frequent face-to-face contact with local suppliers Communication would be difficult to maintain over longer distances -Shipment frequencies of at least once a day and minimal buffer inventories
Research Pattern 1b (rival) Significant local linkages – comprehensive logistics management principles drive proximity but technical information exchange does not	-Customer and majority of material input suppliers located in the same country -Proximity is deliberate -No significant local-for-local R&D departments -Local engineering departments might have face-to-face contact with local suppliers, but the technical information exchange involved is relatively easy to organise with suppliers located further afield -Shipment frequencies of at least once a day and minimal buffer inventories
Research Pattern 2a (target) No significant local linkages – neither comprehensive logistics management principles nor technical information exchange drive proximity, but the principles are appreciated	-The majority of material input suppliers are located abroad and in many cases on other continents -Material inputs from foreign sources will generally require slightly higher buffer inventories than is the case in research pattern 1a and 1b , but the optimal buffer inventory levels are tightly managed involving daily, weekly or bi-weekly shipments -The ownership and geographical location of the buffers may vary -In relation to the minority of suppliers that are located in the same country, proximity is not driven by considerations related to efficient technical information exchange – the operationalisation as regards R&D and local engineering functions is the same as under pattern 1b
Research Pattern 2b (rival) No significant local linkages – neither the comprehensive logistics management principles nor technical information exchange drive proximity, and the principles are not appreciated	-The majority of material input suppliers are located abroad and in many cases on other continents -Material inputs from foreign sources will generally involve high, sub-optimal, buffers amounting to a couple of months' worth of supply Buffer inventory levels are infrequently replenished, i e less than twice a month -The ownership and geographical location of the buffers may vary -In relation to the minority of suppliers that are located in the same country, inventory levels are sub-optimal and proximity is not driven by considerations related to efficient technical information exchange – The operationalisation as regards R&D and local engineering functions is the same as under scenario 1b

Finally, local linkages are not ruled out altogether Again, only in case of a minority of components will characteristics such as high physical volume/weight, high value and great variety of options within a component category lead to close buyer-supplier proximity However, the number of locally manufactured components will be even smaller than in pattern 2a The location of local suppliers "could easily be explained by reference to old arguments about transport costs rather than new ones about 'just-in-time and in one place'" (Hudson, 1994) Where component characteristics do lead to local sourcing, the choice for local suppliers is not driven by considerations related to efficient technical information exchange Thus, the operationalisation as regards R&D and local engineering functions is the same as under *scenario* 1b and 2a

2 6 Assessing the Dynamic Indirect Regional Development Impact

The theoretical contributions of this dissertation concern mainly the extent and causes of local linkage formation associated with NHVP approaches, in non-core European regions This provides important insights into the potential indirect development effects of these plants However, an assessment of the actual contribution of NHVP to a process of self-sustaining, regional development is facilitated by an investigation into the actual impact of local linkages on the quality and competitiveness of the supplier base of a particular region One of the aims of the research project has been to get more detailed insight into the actual impact that NHVP plants have on their suppliers in non-core regions This section outlines the framework that has guided this aspect of the research

The indirect effects of MNEs on regions can be assessed in a 'static' or a 'dynamic' framework (Turok, 1993, Young et al , 1994) Historically, the linkage effects have been assessed within a static framework, focussing on the value of the local linkages, their associated employment, and the impact on the balance of payments In this dissertation, the number of local linkages and the percentage of material inputs are examples of 'static indicators' of development effects for the region To expand on this, and bridging the static–dynamic distinction, an attempt was made to establish the extent to which the demand of the focal companies led to an expansion of production capacity and new company formation in the region

Dynamic frameworks focus on the quality of the linkages and their long-term effect on regional industrial structure and capabilities These dynamic effects are obviously more difficult to measure, partly because of the fact that different host regions start with different levels of industrial capability In this dissertation the approach is taken that dynamic effects occur where the customer-supplier relation involves supplier 'adaptation', i e where local suppliers need to change and upgrade in order to supply Partly based on the categorisation by Gadde and Hakansson (1993), three kinds of supplier adaptation have been selected to serve as dynamic indicators of regional development

First, supplying a MNE might mean that suppliers have to upgrade or expand product technology Second, supplying a MNE customer might mean that the suppliers have to upgrade process technology, e g new machinery or equipment Third, dealing with a MNE customer might involve an upgrade of administrative and organisational routines and standards across all functions, including logistics and inter-firm communication The significance of this last form of upgrading for the process of dynamic development in non-core regions is increasingly recognised (Clancy, O'Malley, O'Connoll, and Van Egeraat, 2001, O'Donnell, 1997)

Given the NHVP drive towards company-wide linkage consolidation the expectation was that the local supplier base would include many subsidiaries of foreign MNEs This idea was supported by findings of similar research in the context of other non-core regions, carried out by the author (Van Grunsven and Van Egeraat, 1999, Van Grunsven, Van Egeraat, and Meijsen, 1995) According to Dicken (1998), local linkages involving subsidiaries of other MNEs are less beneficial for regional development than linkages involving indigenous companies The idea is that indigenous companies generally locate a greater range of functions and establish a higher degree of authority within the region than foreign MNEs As a result, indigenous companies are likely to be more embedded and less footloose, increasing the chance of technology spill-over and further investments For this reason the research established the extent to which the local linkages involved indigenous companies Furthermore, the assessment of adaptation and upgrading at local suppliers was largely confined to indigenous companies only

Active supplier development activities (Jarayam and Vickery, 1998, Lamming, 1993, Rich and Hines, 1997) on the side of the MNE customers are an important medium to enhance the "demonstration effects" (Grabher, 1994, Munday et al , 1995) or "tutoring effects" (Cooke and Morgan, 1998) of MNEs on the regional supplier base Therefore, this research established the extent of these supplier development activities, defined as the "policies, procedures and practices for assessing and improving supplier capability and performance in multiple areas such as quality, design support, and delivery" (Jarayam and Vickery, 1998, p 21) Supplier development can take a variety of forms such as advice, assistance and purchasing seminars organised by the focal firm It can involve dyadic relations as well as the development of suppliers as a group via the formation of supplier associations (Rich and Hines, 1997)

A final strong indication of dynamic effects through linkages is the extent to which the upgrading in technology and organisational routines enable local suppliers to compete more effectively in wider markets (Dicken, 1998) In this research this issue was addressed by establishing the extent to which indigenous suppliers have been able to internationalise on the back of their experience with the focal companies, either through exports or via other forms of internationalisation

2 7 Conclusion

This chapter has described NHVP as a distinct post-Fordist form of industrial organisation and examined existing empirical and theoretical work regarding the associated geography of supply linkages and the implications for regional development in non-core regions

Diverging theoretical ideas exist as to whether the adoption of NHVP approaches will lead to an increase in the extent of local linkages and previous studies on sectors and companies that are generally associated with NHVP approaches report contrasting findings This raises questions that have been captured in the following overall problem statement for this dissertation

> *Do NHVP approaches have significant indirect development effects in the form of linkages, in non-core regions? How does NHVP affect the geography of production linkages?*

The answer to the first part of the problem statement - *Do NHVP approaches have significant indirect development effects in the form of linkages, in non-core regions?* - will contribute detailed information regarding the amount of backward linkages generated by NHVP plants It will also provide a strong and unambiguous basis for answering the second part of the problem statement - *How does NHVP affect the geography of production linkages?* This question aims to test and advance existing theories regarding the drivers behind the geographical configuration of supply chains

Based on a critical analysis of the logic related to the two buyer-supplier proximity drivers most often put forward in relation to NHVP industries, one target research pattern and three rival research patterns were formulated to guide the research The target hypothesis is that NHVP companies in non-core regions have limited local linkages Neither the requirement of efficient technical information exchange nor the requirement of logistical efficiency leads to customer-supplier proximity, not even on a national scale Local engineering groups are mainly involved in non-intensive exchange of technical information with suppliers This information exchange requires limited face-to-face contact and, therefore, does not lead to customer-supplier proximity As regards logistical efficiency, the companies do take account of the comprehensive logistics management principles in managing their supply chains However, these considerations do not lead to buyer-supplier proximity on a national scale Rather, global sourcing, involving managed inventory levels, is the optimal solution for the majority of components

The relevance of these ideas will be tested in a case study of the microcomputer hardware industry in Ireland and Scotland The industry is defined as the industry producing PCs (including laptops and notebooks), workstations and entry level servers (see section 4 1) The industry has been presented as a good example of NHVP (Hudson, 1997c, Kotha, 1995, International Business Week, 03-10-1983 and 14-05-1984, Morgan, 1991, Sayer, 1986) while both countries have traditionally been considered economically peripheral, semi-peripheral or less favoured (e g , Amin et al , 1994, Clarke and Beany, 1993, Morris et al , 1993) Furthermore the industry can serve as a critical case for testing one aspect of the theory – the postulation that customer-supplier proximity is partly dependent on the value and the weight/volume of the supplied components Most of the components used by the microcomputer hardware industry have a low physical volume/weight and a high value Finally, Ireland and Scotland are two peripheral regions that together have attracted the vast majority of (US) foreign direct investment in the microcomputer hardware industry in Europe The size of the activity in both countries present a good context for testing the theoretical propositions Indeed, press articles often suggest the existence of a microcomputer cluster in Ireland (Casey, 1995, Casey, 1997)

Similar research has been carried out previously by Angel and Engstrom (1995) as part of their study of the PC industry in the USA The present research analyses the geography of the microcomputer hardware industry in an entirely different context, that of subsidiaries of multinational enterprises operating in non-core regions Furthermore, in explaining the causes of limited local linkage formation by PC plants in the USA, Angel and Engstrom concentrate on the role of only one possible driver for buyer-supplier proximity efficient technical information exchange The present dissertation also investigates the role of a second driver logistical efficiency

CHAPTER 3 METHODOLOGY

3 1 Introduction

The research involved a case-study research design There are different ideas as to what constitutes a case study Therefore, the following two sections outline the author's interpretation of 'case study' and position it in relation to the distinction between quantitative research and qualitative research The subsequent sections discuss the main components and issues of the case study research process selection of unit of analysis and case, identification of theory, hypotheses and generalisation, data collection, data analysis, validity and reliability

3 2 Quantitative versus Qualitative Approaches to Research

For heuristic reasons, research in social sciences is commonly divided into quantitative and qualitative research approaches or paradigms Based on Creswell (1994), this section briefly outlines the different ontological, epistemological and methodological assumptions of the two stereotype approaches It is important to mention that the contrasts apply to the stereotypes only and that actual studies often combine ideal characteristics of either approach

The quantitative approach has long been the mam approach in social sciences The approach is firmly based in the positivist science tradition On the ontological issue – what is the nature of reality – reality is viewed as independent of the researcher, something that can be measured objectively On the epistemological question – the relationship of the researcher to that being researched – the idea is that the researcher remains distant and independent of that being researched All this has implications for methodology [1] The empirical-theoretical program generally involves the hypothetico-deductive method and the empirical cycle Theories lead to hypotheses that are tested in a cause-and-effect order Concepts, variables and hypotheses are chosen before the study begins The aim of the study is to develop generalisations that contribute to the theory and help to better predict and explain phenomena The praxeological program consists of statistical testing of theories on the empirical reality with a great emphasis on the validity and reliability of the information and instruments Methods for data collection typically include experiments and surveys using questionnaires and structured interviews

Qualitative approaches have been developed as a result of the discussion regarding the shortcomings of the quantitative, purportedly objective, approaches in sociology (Maxwell, 1996, Wester, 1987) Stereotype qualitative approaches incorporate the idea that multiple realities exist in any situation those of the researcher, the individuals being researched, and the audience interpreting the research Here, objectiveness means that the developed theory corresponds closely with the interpretation of the situation by the subjects under research The distance between researcher and those being researched is often minimised rather than maximised As to methodology, an inductive logic often prevails in qualitative approaches Here, the researcher aims to have a more open view of the empirical reality and theory is formulated in the second stage Categories are not identified *a priori* by the researcher but emerge from informants This emergence provides rich context bound information leading to a deeper understanding and theories that help explain a phenomenon The requirement of intensive contact means at least the use of interviews, and often open observation or participation techniques Quantitative concepts such as internal and external validity and reliability are often substituted for other techniques, such as, verification of information with the informants and triangulation

As will be discussed in the following section, textbooks on research design and methodology often treat case study research as qualitative research Apart from the fact

[1] In this section methodology is defined as the process of research, as part of the broader approach to research

that in actual research practice there is no clear division between qualitative and quantitative studies, the author supports the view of other contributors that there are various forms of case study research, some of which have a strong quantitative element

3 3 Case Study Research

The present study was designed as a causal case study There are diverging ideas as to what constitutes case study research It is often treated as a particular form of qualitative research, along with ethnography and grounded theory (e g , Creswell, 1994, Maxwell, 1996, Wester, 1987) Yin (1993) on the other hand believes that the dichotomy between qualitative and quantitative research is unhelpful and argues that case study research is distinct from ethnography and grounded theory as well as from standard quasi-experimental (quantitative) research He defines the case study as an empirical inquiry that investigates a phenomenon within its context, addresses a situation in which the boundaries between phenomenon and context are not clearly evident, and uses multiple sources of evidence

What distinguishes Yin's conception of a case study from traditional quantitative research follows from the concern with context The richness of the context means that the study will have "more variables than data points" (Yin, 1993, p 3) with important implications for generalisation Furthermore, the richness means that the study will likely use multiple sources of evidence that can be quantitative or qualitative This makes statistical analysis difficult or impossible

What distinguishes Yin's concept of a case study from ethnography and grounded theory is the idea that case study research can be explanatory and test theory Along with exploratory and descriptive case studies, he distinguished causal case studies oriented to the testing and advancement of theory and thus part of a cumulative body of knowledge rather than isolated empirical enquiries The traditional idea is that research questions that posit a strong causal relationship between variables suggest some form of experimental research design and the use of statistical tools to make inferences from one's sample to the larger population (Nunan, 1992) Yin on the other hand argues that cause-effect relationships can also be researched with case studies

Within causal case studies Yin distinguishes the factor theory and the explanatory theory The first is one of the most common types of causal theory in social science It involves assembling a set of independent variables and determining which are most correlated with the dependent variable using statistical techniques Although the factor theory is able to determine that 'X' led to 'Y' it does not tell much about the underlying causal processes and the relative importance of the independent variables It is thus poorly specified in terms of cause and effect Furthermore it can only be employed when there are sufficient data points Therefore, factor theory favours survey analysis, although it has its counterpart in case study research

According to Yin causal case study research favours explanatory theories, particularly complex ones Here the researcher uses existing explanatory theories to determine the causal relationship The case study is characterised by a strong adherence to the hypothetico-deductive framework As in traditional quantitative research, theoretical framework and hypotheses/postulations are developed in advance of the data gathering and data analysis process, and the research design involves testing of these hypotheses However, the explanatory theory in a causal case study involves a different approach to design, generalisation, testing and validity

3 4 Unit of Analysis and Case Selection

The unit of analysis limits the boundaries of the case study and helps in the identification of the relevant data to be collected Furthermore, the findings of the case study pertain to specific theoretical propositions about the defining unit of analysis These propositions will be the means for generalising the findings of the case study – to similar cases focussing on the same unit of analysis (Yin, 1993)

The unit of analysis for the present study has been NHVP industries in non-core regions The central postulations guiding the study addressed the impact of NHVP Many of the issues related to NHVP manifest themselves at the level of the supply chain However, it was believed that supply chains were strongly interwoven and that the geographical configuration of individual chains was partly determined by the configuration of the entire industry

Case studies can either have a single-case design or multiple-case design A single-case study focuses on a single case only Multiple-case studies include two or more cases within the same study One of the main advantages of multiple-case designs is that the evidence is considered more compelling The replication yields greater confidence in the robustness of the theory On the other hand, multiple-case studies can require extensive time and resources For this reason, the present study involved a single case the microcomputer hardware industry in Ireland and Scotland The belief was that many suppliers in the two countries would be part of a single cross-border production system

There are at least three criteria for selecting a case topical relevance, criticality for the theory being tested, feasibility and access (Yin, 1993) All three reasons were relevant to the selection of the present case First, the case was relevant to the topic, i e suitable for the phenomenon being studied (Yin, 1984) Companies in the industry had been portrayed as prime examples of NHVP, both in academic literature and other publications (Hudson, 1997, Kotha, 1995, International Business Week, 03-10-1983 and 14-05-1984, Morgan, 1991, Sayer, 1986) Furthermore, both countries were traditionally considered economically peripheral, semi-peripheral or less favoured (e g , Amin, Bradley, Howells, Tomaney, and Gentle, 1994, Clarke and Beany, 1993, Morris, Munday, and Wilkinson, 1993)

At the same time the microcomputer hardware industry represents a critical case in testing one part of the theory – the causal relation between logistical efficiency and customer-supplier proximity One of the propositions is that this relation is partly dependent on the value and the weight/volume of the supplied components Most of the components used by the microcomputer hardware industry have a relatively low physical volume and a high value and for this reason the industry can serve as a critical case

Another reason for selecting the case concerned feasibility and access Ireland and Scotland were relatively convenient research locations for the researcher Together, both countries had attracted the vast majority of (US) foreign direct investment in the microcomputer industry in Europe (see section 4 4) The sheer size of the activity in these two countries presented a suitable context for testing the theoretical propositions

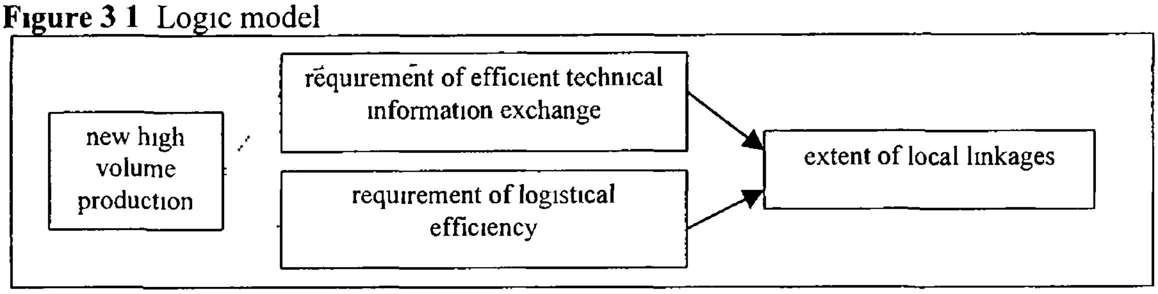
3 5 Theory, Hypotheses and Generalisation

The causal case study is characterised by a strong adherence to the hypothetico-deductive framework Problem statement or research questions are related to existing theories regarding phenomena and decomposed into a series of causally linked hypotheses These hypotheses are subsequently tested and the findings are generalised

As regards the problem statement, the case study approach is most appropriate for 'how' and 'why' questions, i e questions that are looking for an explanation rather than a prediction of a phenomenon (Yin, 1984) The 'how' question of the present study looked for an explanation of the geography of production linkages – how does NHVP affect the geography of production linkages? Because this geography was not clear at the outset of the study a 'what' question was included as well – do NHVP approaches have significant indirect development effects in the form of linkages, in non-core regions? The initial design also included a question about the *direct* development effects of NHVP and information on this topic was collected However, halfway through the research project a decision was taken to focus the research on the indirect effects, partly because of the limited quality of the data on direct development effects (see section 3 6 2)

A great body of research has been carried out by other researchers leading to various theories as to the geographical outcome of new production concepts and the processes involved These theories have been outlined in Chapter 2 These theories led to the formation of a set of causally linked hypotheses together representing the target research pattern or target hypothesis of the study The most simple logic model involved one main independent variable – the adoption of NHVP – and one dependent variable – the extent of local linkages (see Figure 3 1) Two aspects of NHVP were identified as the main theoretical drivers for local linkage formation the requirement of efficient technical information exchange and the requirement of logistical efficiency

Figure 3 1 Logic model



Most variables and other theoretical concepts were deliberately rather loosely defined For example, the highly abstract concept of NHVP referred to a wide range of flexible production models, all with a particular detail and emphasis Although the concept was loosely defined, great effort was made to identify and describe the generic elements of the various models Similarly, the requirement of efficient technical information exchange and the requirement of logistical efficiency were not precisely defined In fact, the precise meaning of these issues in the microcomputer industry was one of the main subjects of the case study and was to be based on the respondents' own interpretation as discussed during the interviews

The definition of the term 'local' was rather problematic In principle, 'local' was defined as the territory of either Ireland or Scotland The clear socio-political delineation of the two territories provided the study with obvious policy relevance and both countries had often been considered as units in regional development theory (e g , Amin et al , 1994, Krugman, 1997) However, the geographical configuration of production networks was strongly determined by the decisions of enterprises, notably MNEs, and for these enterprises, 'local' might well have meant 'national' or 'regional' in the broader supranational sense (Dicken, Forsgren, and Malmberg, 1994) Therefore, in working towards an explanation of the geographical configuration of production networks it was considered helpful to adopt a flexible definition of the term 'local' Thus, 'local' linkages were inventorised and measured at both the level of the individual countries as well as at the level of the 'British Isles' Similarly, the relevance of the various drivers for 'local' linkage formation were investigated in the context of suppliers located in the same country as well as elsewhere in the British Isles Related to all this, where appropriate, the dependent variable, 'extent of local linkages', was substituted for other concepts that better captured the imprecise spatial scale relevant to the various drivers, notably 'reduction of the linkage distance' and 'increasing buyer-supplier proximity'

The 'measurement' of the various elements of NHVP, the extent of local linkages and the relevance of the two main drivers for local linkage formation involved both qualitative and quantitative data Some of the information could not be readily converted to numerical values However, to facilitate a quasi-statistical analysis (see below), quantitative data were collected where possible

The causal case study involves a specific approach to testing and generalisation, generally referred to as analytical generalisation (Hamel, 1993, Yin, 1993) This can be contrasted to the traditional quantitative approach of statistical generalisation In a traditional quantitative survey design the individual cases represent a sample of a larger population to which the findings are generalised after statistical testing This approach is not suitable for a case study A case study calls for intensive amounts of data about a small number or a single unit of analysis The number of subjects or data points is so small that it cannot outnumber the variables of interest In other words, "the degrees of freedom would always be insufficient compared to the number of variables" (Yin, 1993, p 81) Furthermore, many of the required data cannot be readily converted to numerical values Both characteristics make statistical testing and generalisation to a larger population irrelevant

Instead, "generalisation of the results of a case study is made to theory, and not to populations" (Yin, 1993, p 79) This means that the researcher identifies a theory that the case study is trying to test, rather than regarding the individual case studies as data points or part of a sample The theory will provide a predicted pattern of events, which becomes a series of benchmarks, a template, against which empirical results can be compared In this way theory can be tested with empirical evidence collected from a single-case study Multiple case designs are based on a replication logic rather than a sampling logic Replication simply yields greater confidence in the robustness of the theory

Similarly, the results of this case study of the microcomputer hardware industry in Ireland and Scotland cannot be generalised to all other NHVP industries Rather, theories about the geographical configuration of these other NHVP industries are the target to which the results could be generalised However, this generalisation is not automatic In principle, the theory must be tested through replication of the findings in a second or even third NHVP industry Once such replication has been made, the results might be accepted for a much larger number of similar industries (Yin, 1984) Prime candidates for generalisation would be theories about the geographical configuration of the consumer electronics industry, the telecommunications hardware industry and the car industry Thus, apart from providing an explanation for the case of the microcomputer industry, in principle the present case study serves as one element in a broader academic process of cumulative theory formation in which future case studies will further support, refine or adapt the developed target theory

However, the case study of the microcomputer hardware industry in Ireland and Scotland might be considered to have 'face-generalisability' (Maxwell, 1996), i e there is no obvious reason *not* to believe that the results apply more generally

3 6 Data Collection

Research data can be collected from various sources Traditional qualitative research generally involves a survey or an experiment In a survey, individuals in a sample of the population are asked the same set of questions and the answers are subsequently statistically analysed The questions can either be mailed to the respondent, administered in a face-to-face interview or gathered through telephone interviews (Creswell, 1994) The main advantages of the postal questionnaire are the low cost and time requirements One of the main downsides is that the response rate is generally very low, particularly where questionnaires are rather long A further drawback is that there is no opportunity for the researcher to probe beyond the written answer Face-to-face interviews on the other hand have a higher response rate, allow for more extensive questionnaires and provide the opportunity to probe the answers provided Furthermore, the face-to-face contact provides the interviewer the opportunity to build rapport with the interviewee, thereby raising co-operation The main problem is that the method can involve enormous time and costs This problem is somewhat reduced by the use of telephone surveys But, like the postal questionnaire, the telephone survey is less suitable for extensive questionnaires Furthermore, it does not allow for questions that require the consultation of filed information

Data collection for case studies can involve six different sources of evidence interviews, documentation, archival records, direct observations, participant observation and physical artefacts (Yin, 1984) Most relevant in the context of the present study are interviews, documentation and direct-observation

Interviews are one of the most important sources of case study information The interview is generally of a different nature from that in a traditional survey A good understanding of phenomena and causal processes often requires data that are not readily converted to numerical values Questions can be more open and answers more elaborate Interviews may take several structures, ranging from unstructured or open-ended to structured (Yin, 1984) The unstructured interviews are conversations during which the interviewee is invited to discuss the facts of a matter In contrast, in a structured interview, the interviewee strictly follows the order of questions laid down in a questionnaire Many case studies make use of semi-structured interviews that guarantee the discussion of a number of core questions while at the same time leaving room for elaboration and manoeuvre

Documentation as a source of data may include public documents such as newspapers, internal administrative documents, private documents such as letters, as well as formal studies of the same case According to Yin (1984), the usefulness of these documents is not based on their necessary accuracy or lack of bias In fact, many documents must be carefully used and should not be accepted as a true representation of events that have taken place The most important use of documents is to corroborate and augment evidence from other sources If the documentary evidence is contradictory, the researcher has specific reason to inquire further into the topic

Direct observation involves the researcher visiting and observing the case study site Observations can range from formal to casual data collection activities (Yin, 1984) Formal observations involve the development of protocols and the researcher may measure the incidence of certain processes Less formal observations might be made throughout a field visit, including those occasions during which other evidence is being collected Observational evidence can often serve to provide additional information and a better understanding about the topic

Because of the volume and sensitivity of the data required, the main source of evidence in the present study was interviews while documentation and direct observation were used to some extent as well Furthermore, part of the data was collected via a postal questionnaire but these data were never meant to become the subject of statistical analysis in the context of a traditional survey research design The main interview data were collected in three phases The initial research design involved two phases The first phase was primarily used to collect data on the geographical configuration of the production networks of the microcomputer industry in Ireland and Scotland The other purpose of this first phase was to obtain a broad feedback from the companies as to the relevance of some of the main concepts and theories in the initial research design This information could than serve to fine-tune the research hypotheses and the questionnaire for the second phase After the second phase, and based on findings of this second phase, the idea was that the dissertation would gain from additional primary data, and it was decided to include a third phase of data collection The three phases are discussed below

3 6 1 Phase One

The microcomputer hardware industry can roughly be divided into system assemblers and component manufacturers Partly based on time and cost considerations, it was decided that the brunt of the required data would be collected by interviewing the assembly companies Although supplier companies could have provided an additional perspective regarding the spatial configuration of the production network, the belief was that the relevance of the hypothesised drivers could be investigated by interviewing only the assembly companies A selection of supplier companies was actively involved in the study However, their involvement was limited, with the main purpose to check or complete information provided by the informants in the assembly companies, e g in case informants could not provide the requested information or in case the information from different sources proved contradictory

In early 1998, a comprehensive list of companies with system assembly facilities in Ireland and Scotland was compiled with the co-operation of staff at the industrial development agencies in the two countries IDA Ireland and Scottish Enterprise The list included 11 multinational branded computer companies, three contract electronics manufacturers and three very small indigenous start-up companies It was decided only to seek the active involvement of the 11 main branded microcomputer assemblers The plants of the contract assemblers were basically an extension of the facilities of the main computer assemblers and the idea was that the production concepts and geographical configuration of the supply network would not differ much from those of their main customer The small indigenous start-up companies were excluded on the basis of their small volumes, which meant that they could not have adopted NHVP approaches

The limited number of major microcomputer assemblers m Ireland and Scotland made it possible to actively involve all the main firms in the case study The length of the interviews and the multi-phase design of the data-collection process required a great commitment of management in the focal companies For this reason great effort was made to ensure co-operation First, the two industrial development organisations were asked to support and facilitate the project Letters outlining the research proposal and containing a request for support were sent to the Chief Executives of the two organisations Both executives expressed their support for the project and appointed a senior staff member to facilitate the study Mr Alex Bryce, Manager Information Industries Group, Locate in Scotland at Scottish Enterprise and Mr Donal Murphy, ICT Division East Coast/Mid-West USA & Asia, IDA Ireland Being the principal investment promotion and support bodies, both organisations had substantial leverage over the target companies and the two senior staff members were well acquainted with target companies' management

The two agencies sent a letter to the most senior executives at the 11 target companies, introducing the project, expressing support and requesting co-operation Subsequently, the executives were contacted by phone and a second letter was sent by the researcher with a more detailed outline of the research project, a mention as to the multi-phase nature and a suggestion regarding the most appropriate staff member for the first interview, i e the Materials Manager or the Purchasing Manager (see Appendix A 1) All 11 target companies expressed their willingness to co-operate with the multi-phase research project The 11 companies, from here on referred to as the focal companies, are listed in Table 3 1

The first round of interviews in Ireland was conducted in November 1998 Intel had already closed its system assembly plant (ESSM) in the second quarter of 1998 However, it was believed that interviews would still offer important insights regarding the main research question For this reason interviews with former staff were conducted on a post-hoc basis, with reference to the second quarter of 1998 Similarly, interviews at AST-Samsung were conducted on a post-hoc basis, with reference to the second quarter of 1998, just before AST stopped assembling desktops and servers in Ireland Although AST-Samsung was still assembling portable computers in November 1998, the belief was that the situation during the first half of 1998 would provide a fuller picture of a NHVP plant As regards the focal companies in Scotland, all but one of the first-phase interviews took place in February 1999 Packard Bell-NEC delayed the first interview for internal reasons until the third quarter of 1999 In nearly all cases the interviews were conducted with the Materials or Purchasing Manager or a staff member with an equivalent remit or knowledge In many cases staff members with responsibility for specific commodities joined the principal interviewee for part of the interview

Table 3 1 Co-operating microcomputer assembly companies in Ireland and Scotland

Ireland
Apple Computers, Cork
AST Research, Limerick
Dell Computer Corporation, Limerick
Gateway Computers, Dublin
Intel Ireland, European Site for System Manufacturing (ESSM), Leixlip
Scotland
Apricot-Mitsubishi, Glenrothes
Compaq Computer Manufacturing, Bishopton
Digital Equipment Corporation, Ayr
IBM UK, Greenock
Packard Bell-NEC, Livingston
Sun Microsystems, Linlithgow

As regards the structure, the interviews consisted of two parts – both guided by a questionnaire designed for the purpose (see Appendix B 1) The first part of the interview served to collect a limited amount of data regarding the background and activities of the focal companies – partly to facilitate the flow of the second part of the interview – as well as a preliminary investigation of the relevance of some of the main concepts and theories in the initial research design. As regards the latter facet, the interview was semi-structured allowing for elaboration and manoeuvre.

The second part of the interview served to collect data on the geographical configuration of the supply chains of the focal companies. This part of the interview was highly structured, involving the completion of a table listing the different material inputs. It was, however, not exactly the same for every company. In order to be as complete as possible, as well as to save time during the interview, the listing of relevant material inputs was customised to the particular situation of the individual focal companies and data on suppliers obtained from other sources was integrated in the questionnaire. After completion of the table, as an extra check, interviewees were shown a list of existing component manufacturers in Ireland and Scotland and were asked if the list included suppliers to the focal companies. The information used for customising the questionnaire and for compiling the list of existing component manufacturers had been obtained through documentation research.

Documentation included newspaper articles, corporate annual reports and corporate Internet web-sites. Since the first quarter of 1996 and for the entire duration of the research project the researcher systematically collected newspaper material, referring to the computer industry in Ireland, mainly published in *The Irish Times* and *The Sunday Business Post*. Abstracts were filed in a computer database that included all microcomputer assemblers and suppliers. From 1998, material on the microcomputer industry in Scotland was included as well, mainly published in the on-line edition of *The Scotsman.*

The broad design of the questionnaire was piloted at the Irish subsidiaries of two MNEs involved in NHVP. This piloting did not lead to major changes in the broad design, other than a greater division of one of the questions in the first part of the questionnaire and a slightly different layout of the component table. The detail of the questionnaire, particularly of the second part, was very specific to the microcomputer assemblers, which meant that it could only be tested in such companies. However, given the research design, the questionnaire could not be piloted in any of the major microcomputer assemblers in Ireland or Scotland. Instead, it was decided to use the interview at the first company to gather the required information as well as to 'test' the design. The company agreed to co-operate in the design process by granting two interviews with two different staff members in this first phase. The first interviewee answered the questions in the first part and discussed the design of the entire questionnaire. This led to a further specification of one of the questions in the first part of the questionnaire, as well as the addition of component categories in the second part. Subsequently, the second interviewee answered the questions in the second part of the questionnaire. The remaining focal companies all worked with the same questionnaire except for the fact that questionnaires were customised to individual focal companies (see above).

The decision was taken to tape-record and fully transcribe the interviews. There are obvious disadvantages of tape-recording an interview, notably the fact that interviewees tend to be more 'reserved' in answering questions. However, tape-recording was used for several reasons. Tapes provide a more accurate rendition of interviews than any other methods (Yin, 1984) and allow for the incorporation of quotes in the reporting process. Furthermore, compared to making notes, tape-recording saves interview time without losing valuable information. All interviewees were asked permission to tape the interviews and were told they were free to turn off the tape at any moment, a privilege used in a number of cases. In spite of the interviews being recorded, hand notes were made to prevent data being lost in case of recorder failure as well as to facilitate the interview process.

After transcription, the interviews were followed up by an e-mail message, outlining the gaps in the provided information and the request for completion. The interview information was checked with information on suppliers obtained from other sources (mainly newspaper articles and corporate web-sites). Discrepancies and remaining gaps were addressed during the second round of data collection.

Finally, further information was collected through direct observation Six focal companies granted the researcher's request for a site tour, sometimes directly following the interview Observation was relatively informal and the main purpose was to increase the researcher's understanding of the logistics processes in relation to the assembly processes as discussed during the interviews Furthermore, the tours did provide an opportunity to supplement and corroborate some of the information provided during the interviews

3 6 2 Phase Two

After fine-tuning of the research hypotheses, the plan was to collect all the required information in a second phase of data collection Again, interviews were to be the main source of evidence but an important part of the information was obtained via postal questionnaires Documentation research was used as well

The second round of interviews was conducted during the second half of 1999 All senior executives contacted for the first round of interviews were sent a letter reminding them of their commitment to the multi-phase research project (see Appendix A 2) The Intel ESSM plant was now closed for over a year and the Digital business was in the process of integrating with Compaq However, the requested data pertained to the situation during the time the first interviews were conducted so both companies were still included in this second round Given the wide-ranging nature of the requested information, and in an effort to spread the interview load, the executives were requested to put forward for interview a number of staff members with knowledge of the following areas materials/purchasing, logistics, corporate organisation, investment, R&D and human resources All companies, except Intel, co-operated in the second round of interviews The number of staff members interviewed in this second round ranged from 2 to 7 and typically included the General Manager or executive with equivalent seniority, the Materials/Purchasing Manager, and the HR Manager Where focal companies had a significant development function, interviews were conducted with the head of the development group (see list of interviews following the bibliography)

The interviews were semi-structured and guided by questionnaires designed for the purpose (see Appendix B 2) The main interview items included general company information, corporate organisation and structure, customer relations, the assembly factory, the supply chain, local impact, logistics, product and process development, and human resources A number of questions on the issue of local impact, not exclusively positioned in the section with the same name, were included to gain more detailed figures on static as well as dynamic indicators of the regional development effects of the local linkages created by NHVP plants [2] Questions regarding human resources were mainly included to obtain data required to address a research question about direct regional development effects, that had been part of the initial research design (see section 3 5) However, partly because of the lower quality of the collected data (see below), but mostly for reasons related to focus and size, it was decided not to include these issues in the present dissertation and most of the related data were left unused [3]

The various items were divided over separate questionnaires, so as to suit the particular remit and expertise of individual interviewees and to spread the interview load Because of the fact that the number and function of interviewees in the focal companies varied, the content and layout of questionnaires was different in each company In order to prevent confusion, the individual questions were not numbered – the questionnaire presented in Appendix B 2 has been numbered and slightly modified for the purpose of discussion Most questions were of an open nature However, with the view of using quasi-statistics (see below), quantitative data were collected as well, often using a Likert scale of 1 to 7

[2] Although the theoretical contributions of the dissertation concern mainly the extent (static effects) and causes of local linkage formation associated with NHVP approaches, one of the aims of the research project was to get more detailed insights into the dynamic effects of these linkages, i e the effect on the quality and competitiveness of the local supplier base (see section 2 6)

[3] Some of the material on direct regional development effects with respect to four focal companies in Scotland, has been included in an earlier paper by the author (Van Egeraat, 1999)

Like in the first round of interviews, to some extent the questionnaires were customised to the individual focal companies First, existing information from the first interviews was included in the questionnaire so that a number of questions could be skipped, depending on the extent of the information provided during the first interview Furthermore, a number of questions specifically built on the information provided in the first round of interviews and these data, notably supplier names, were integrated in the questionnaire Secondly, existing information obtained by documentation research was included in the questionnaire copy of the interviewer However, here the aim was not to save time Rather, the information was included as part of a triangulation process In order not to influence interviewees' answers, the existing information was not included in the interviewees' copy When the answers provided did not corroborate the existing information, the discrepancies were discussed Thirdly, not all questions were relevant to all focal companies and the irrelevant questions were not included in the questionnaire

For the reasons discussed in relation to the first round of interviews, the second questionnaire could not be piloted in any of the major microcomputer assemblers Furthermore, because of its highly sector specific nature, it was the researcher's opinion that the questionnaire could not be tested in a different sector For these reasons the decision was taken not to test the overall design of the questionnaire However, some central questions had been tested at the earlier-mentioned Irish subsidiaries of two MNEs involved in NHVP, notably Q8, Q9, Q10, Q11, Q36-Q40, Q42, Q48 and Q66 Other than a reduction in the categories of Q11, this testing did not lead to major changes Furthermore, some questions, in adapted form, had proved valid in earlier studies carried out by the researcher (Van Egeraat, 1995, Van Grunsven and Van Egeraat, 1999), notably Q1-Q6, Q8, Q45, Q47, and Q49 Like in the first round of interviews, the first company to be involved in the second round of interviews was used to 'test' the overall design, mainly with respect to the size of the questionnaire This led to the decision to omit a number of questions from the questionnaire Furthermore, in relation to the various tables in the questionnaire, companies supplying similar inputs were put together in one cell, although the interviewees were asked to differentiate between suppliers where relevant

For the reasons discussed in relation to the first round of interviews, all interviews were tape-recorded and fully transcribed Some of the questions, particularly many of the tables in the section on human resources, required the consultation of filed information and were left unanswered during the interview After transcription, the interviews were followed up by an e-mail message outlining the gaps in the provided information and the request for completion The quantitative data were analysed using the descriptive statistics functions of Microsoft Excel

As to the quality of the response, the majority of questions were addressed very satisfactorily The exceptions concerned the questions on human resources Although valuable information was collected from all focal companies, in a number of companies some of the questions remained unanswered, probably due to the exceptional detail that was requested This situation persisted, despite numerous follow-up e-mails, letters and phone-calls

Although most information could have been collected in the face-to-face interviews, a postal questionnaire was included in order to save valuable interview time (see Appendix B 3) The postal questionnaire only contained questions regarding the relevance of NHVP concepts for the focal companies The questionnaire was highly structured The various questions were posed using a Likert scale of 1 to 7, where 1 indicated a weak match with textbook NHVP while 7 indicated a very strong match, although the actual wording depended on the particular question The Likert scale was used to obtain data that could serve as 'quasi-statistics' (see below) and not with the idea of obtaining data suitable for statistical analysis in the context of a quantitative research design The questionnaire was largely designed for this project, although the idea of using a Likert scale and the formulation of a number of the questions were inspired by Pine's (1993) study of mass customisation

The postal questionnaire was piloted at the Irish subsidiary of one MNE involved in NHVP Furthermore, the make-up of the questionnaire was discussed with the respondent This process lead to a reduction in the number of questions as well as small changes in the wording

The questionnaire was sent to the general managers or executives with equivalent seniority/remit before the main interview In order to increase the response rate, as well as to create opportunities to address gaps in the information, and further explore unexpected answers, the respondents were asked to return the questionnaires before the interview After a brief first analysis, the gaps and unexpected answers were discussed during the interview Ten companies agreed to co-operate but only nine questionnaires were returned The data were analysed using the descriptive statistics functions of Microsoft Excel software package

Finally, as in the first phase of data collection, documentation included newspaper articles, corporate annual reports and corporate Internet web-sites In addition, corporate material such as internal newsletters and marketing material, obtained during the first site visits was used as well

3 6 3 Phase Three

After preliminary analysis of the data collected during the first two phases it became clear that the dissertation would gain from an additional round of primary data collection The questions, in particular Q51, had proven to be not specific enough to fully capture the component-specific detail of the inbound logistics pipelines The dissertation required more detailed data on inbound inventory levels, mode of transport and shipment frequency

For this reason the focal companies were interviewed for a third time in the second quarter of 2001 By this time, two of the original 11 focal plants, Intel ESSM and Apricot, had closed while the original Digital facility was now part of Compaq However, the requested data pertained to the situation during the time the first interviews were conducted Therefore both the Apricot-Mitsubishi facility and the old Digital plant were included in this third phase Intel had already opted out in the second phase Given the subject matter and the period under consideration, the co-operation was sought of the Materials or Logistics Managers who were involved in the first and second round of interviews Some of the original interviewees had moved to different positions or even different companies However, in most cases contact had been maintained so that in eight cases the original interviewees could be contacted, although some of them were no longer employed at the focal companies In two other cases, new contact was established with relevant staff via the chief executives Care was taken that new interviewees could provide data on the period 1998-1999 In the end, the staff of eight focal companies agreed to be interviewed

The interviews were structured and guided by a questionnaire containing a single table listing material input suppliers (see Appendix B 4) In principle the questionnaires could have been administered by post However, interviews were chosen in order to increase the response rate and guarantee the quality of the answers provided Furthermore, interviews provided the possibility to discuss unexpected answers In order to save time and costs, all interviews were conducted over the telephone The downsides of telephone interviewing were considered less relevant given the existing rapport built during earlier interviews The questionnaires were customised to the extent that the tables listed the suppliers of individual focal companies Furthermore, information collected in the first two interviews had been included which meant that tables were often already completed to a considerable extent, particularly columns two, three, four and five

Questionnaires were forwarded in advance of the interviews as an aid for the discussion All interviews were recorded and fully transcribed After transcription, interviews were followed up by an e-mail message outlining the gaps in the provided information and the request for completion

Given its straightforward nature, the questionnaire was not piloted The only concern was that the interview might require too much time In relation to this, the first interview was conducted with an interviewee who had proved very co-operative The interviewee was informed of the draft nature of the questionnaire and after the interview the length of the questionnaire was discussed No changes were deemed necessary

In the same period, very short telephone interviews were conducted with staff at a selection of local supplier firms (see list at end of bibliography) The interviews were used when interviewees at the focal companies were unable to provide the requested information In some cases these supplier interviews were used as a final check, when information from different sources proved contradictory

Finally, during this last phase and at the start of the research project a small number of semi-structured face-to-face interviews were conducted with staff at the two industrial development agencies and other informants on the development of the microcomputer industry (see list at end of bibliography) The main aim of these interviews was to obtain information regarding the development of the microcomputer industry in Ireland and Scotland The interviews were guided by questionnaires The content of the questionnaires was highly customised to the particular agency and geared towards filling gaps in information left after documentation research

Overall, the vast majority of evidence was collected using various semi-structured or structured questionnaires Data-collection regarding the various elements of NHVP, the extent of local linkages and the relevance of the two main drivers for local linkage formation involved a great number of related questions, spread over these questionnaires To facilitate the establishment of a 'chain of evidence' (see section 3 8 1), Table 3 2 relates the main elements of the logic model to the questions in the questionnaires that addressed these elements Questions regarding the issues of technical information exchange and logistics have all been included in the general category of 'the supply chain' However, because of their centrality to the dissertation, separate rows have been included for these two issues as well As will become clear from this dissertation, the various elements of NHVP are strongly related This has been reflected to some extent in the fact that some questions are pertinent to a number of elements

Table 3 2 Main research issues and corresponding questions in the questionnaires

Customer relations	Postal questionnaire 1-17, 62-63 Interview 2 12-14
Product and process development	Interview 1 6-7 Postal questionnaire 18-25 Interview 2 53-56, 59-64
The assembly factory	Interview 1 5 Postal questionnaire 13, 26-41 Interview 2 15-21, 68
The supply chain	Interview 1 5, 7, 8 Postal questionnaire 42-56 Interview 2 22-30, 30-41, 48-52, 57-58
Supply chain and logistics	Interview 1 5, 7, 8 and column 4 of table Postal questionnaire 44-46, 54 Interview 2 34, 40, 48-52 Telephone interview 3 Table
Supply chain and technical information exchange	Interview 1 5, 7, 8 Postal questionnaire 53 Interview 2 31-33, 56-58
Corporate organisation and structure	Interview 1 1-4 Postal questionnaire 57-59 Interview 2 7-11, 28, 37, 60-64
Geography of linkage structure	Interview 1 column 2-3 of table
Actual impact of focal companies on local suppliers	Interview 2 38, 42-45
Human resources (direct development impact)	Interview 2 2-6, 42, 46, 47, 68-72, 76-77, 79-86

3 7 Data Analysis

Data analysis has been one of the least developed components of the case study approach One popular strategy has been pattern-matching where an empirically based pattern is compared with a predicted one, or with several alternative or rival predictions These patterns may be related to the dependent variables, the independent variables (or explanations), or both (Yin, 1984, Yin, 1993)

In principle the target theory or set of hypotheses could be tested by simply comparing the empirical data to the target theory However, a more potent strategy for analysis involves the development of rival theories in the design In traditional quantitative research the most common rival theory is the null hypothesis, i e the absence of the target hypothesis However, in case studies the best rival is not simply the absence of the target theory Instead, the best rival theory is a theory that explains the same outcome but with a different theory than that of the target theory The researcher should then collect the data needed fairly, to give each rival theory an opportunity to be proven (in-)correct after which the results can be compared in a pattern-matching process

There is no precise way of setting the criteria for the precision of pattern-matching, i e for deciding how close the empirical findings have to be to the predicted pattern to be considered a match Statistical tests are often irrelevant This lack of precision raises the problem of interpretative discretion on the part of the researcher As a result it is advisable not to postulate very subtle patterns "One wants to do case studies in which an eyeballing technique is sufficiently convincing to draw conclusions" (Yin, 1984, p 107)

At the outset of the present case study neither the dependent variable, the extent of local linkages, nor the independent variables, or rather the explanation, were given as fixed Accordingly, the developed patterns were related to both the dependent variable and the explanation In its simplest form the target theory was the following In the microcomputer hardware industry in Ireland and Scotland, neither the requirement of efficient technical information exchange nor the requirement of logistical efficiency instigate customer-supplier proximity, although the comprehensive logistics management principles are appreciated As a result, there are no significant local linkages Three rival theories were developed, incorporating different outcomes and/or different explanations (see section 2 5) As much as possible the rival theories were developed to be mutually exclusive from the target theory

3 8 Validity and Reliability

There is no consensus on addressing traditional topics such as validity and reliability in case studies Some qualitative researchers prefer a different language, notably the concept of 'verification' (Creswell, 1994) Others adhere to the traditional concepts but frame them within the procedures that have emerged from qualitative work Thus, Yin (1984) distinguishes four relevant tests construct validity, internal validity, external validity and reliability

3 8 1 Construct Validity

Construct validity refers to the establishment of correct operational measures for the concept being studied To meet the test of construct validity, a researcher should clearly identify the subject of study and concepts and the selected measures should reflect the specific concepts that have been selected

The subject of study in the present case study was relatively straightforward, so construct validity was relatively easy to attain Thus, apart from the issue of scale, the extent of local material input linkages was a relatively straightforward concept that could be directly measured or outlined in detail, provided co-operation was obtained Still, great care had to be taken only to measure the material inputs actually manufactured by local suppliers, and not the material inputs *bought* from local suppliers The researcher expected that these two measures had been confused by respondents in other, survey based, studies (see, section 4 4 1) The concept of NHVP was less straightforward but the various elements of the concept were worked out in great detail Similarly the two theoretical drivers for local linkage formation, although loosely defined, were thoroughly analysed

A study can gain in construct validity by the establishment of a clear 'chain of evidence' (Yin, 1984) The principle is that the reader is allowed to follow the derivation of any evidence from initial research questions to ultimate case study conclusion The reader must be able to move from one section of the case study to another, with clear cross-referencing to methodological procedures and to the resulting evidence A similar chain of evidence was established in the present dissertation The various sections systematically address the various elements of the argument, as laid down in the target and rival hypotheses Methodological procedures and limitations were discussed, relevant questions in the questionnaires were identified and supporting data were presented, either in the text or in the appendices

3 8 2 Internal Validity

Internal validity concerns the identification of a causal relationship, whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationships The concept concerns mainly the threat of concluding that a particular factor x caused a particular event/situation y, without knowing that a third factor may have been responsible However, it can be extended to all cause-and-effect inferences based on the data collected as part of a case study (Yin, 1984) Relevant questions include Is the inference correct? Is the evidence convergent? Does it appear to be airtight? In the present study, the main strategies to rule out threats to the internal validity included the development of rival theories, triangulation, the use of rich data and quasi statistics

One of the most favoured strategies towards internal validity is the development of a priori rival theories and the collection and analysis of data to test these rivals This strategy was also central to the design of the present case study, which included the development of one target and three rival theories (see section 3 7) As discussed, the stronger the contrast between the rival theories, the better the chance that internal validity will be achieved As much as possible, the rival theories for the present case study were developed to be mutually exclusive, although the various theories shared *elements* of explanation and/or outcome As expected, the empirical reality was not entirely black and white Thus, not all of the data fitted neatly in one and the same rival pattern However, the results are considered strong enough to claim internal validity

Triangulation involves the collection of information from a diverse range of individuals or other sources of evidence, to be used in convergent lines of inquiry (Maxwell, 1996, Yin, 1984) Any findings or conclusions are likely to be much more valid if they are based on different sources of information that corroborate each other As discussed under the section on data-collection, in the present case study data from different interviews at the same focal company were compared and data from interviews were compared with evidence from documentation research Furthermore, where evidence from different sources was in conflict, discrepancies were addressed on the spot or during follow-up interviews and evidence from a different source – supplier interviews – was used where conflicts were not resolved

The strategy of triangulation exposed a great deal of misinformation that, if left undetected, could have confused the data analysis; and most conflicts were satisfactorily resolved Furthermore, the practice of 'on-the-spot' comparison made interviewees noticeably more prudent, leading to more valid data

Internal validity was also supported by the use of rich data These are data that are detailed and complete enough to provide a full picture of what is going on (Maxwell, 1996) This reduces the possibility that the interviewer only notes what supports his expectations Rich data are a basis to test rival theories, rather than merely a source of supporting data In the present study these data were obtained by word-for-word transcription of the interviews, rather than by simply making notes of what was considered significant The transcription also included the words of the interviewer This made it possible to identify instances where the interviewer made specific suggestions as to the possible answer to a particular question Because of this, in a number of cases information was treated with extra caution

Finally, quasi-statistics refers to the use of simple numerical results that can be readily derived from the data (Maxwell, 1996) This not only allows the researcher to test and support claims that are inherently quantitative, but also facilitates an assessment of the *amount* of evidence in the data that bear on a particular conclusion This strategy was used to a great extent in the present case-study The number of times certain phenomena had been observed was generally explicitly identified, often in tabular format

Furthermore, where possible, information was collected in *quantitative* form, which allowed for an extensive use of simple descriptive statistics

Overall, the various strategies have helped to obtain internal validity The main threat to the validity of the conclusions was related to the fact that the majority of suppliers were not interviewed The focal companies were able to provide a great deal of information on the inventory levels at the suppliers' manufacturing facilities, particularly in relation to suppliers located in Ireland and the UK However, the focal companies generally did not have precise insight into the inventory levels at suppliers' manufacturing facilities in other continents, notably South-East Asia As a result, some of the inferences regarding the efficiency of the overall logistics pipeline are based on the (informed) suppositions of interviewees, feedback from academics[4] and the author's own logically deduced ideas as to the production and logistics systems of suppliers in other continents (see section 5 5 2) However, in principle, this element of the argument is not 'airtight'

3 8 3 External Validity

External validity establishes the generalisability of the findings As discussed, the design of the case study does not allow for the statistical generalisation of the findings to other NHVP industries On the other hand, the *a priori* specification of theoretical relationships allows for analytical generalisation In principle, the theory must be tested through replications of the findings in a second or even third NHVP industry Thus, the present case study will serve as one element in a broader academic process of cumulative theory formation in which future case studies will further support, refine or adapt the theory

[4] Initial interpretations of the collected data on logistical efficiency were discussed with other academics with a particular interest in the subject matter, notably Dr Philip McCann, Department of Economics, University of Reading

3 8 4 Reliability

The reliability issue concerns the question whether the operations of the study, such as data collection procedures, would produce the same results if repeated The goal is to minimise the errors and biases in a study Furthermore, reliability allows for the case study to be replicated in a different setting

Reliability of the present case study was strongly facilitated by the reliance on interviews using semi-structured and structured questionnaires, which made the data-collection process very transparent Furthermore, reliability was supported by the development of a 'case study database', as suggested by Yin (1984) Thus, tapes of all interviews were kept All transcripts of interviews and other documentation were filed, categorised by individual focal company Similarly, the abstracts of newspaper articles on supplier companies were stored in a computer database and hardcopies of the full articles were kept as well All information can be accessed on request

3 9 Summary

This dissertation is a causal case study of the microcomputer hardware industry in Ireland and Scotland The study is characterised by a strong adherence to the hypothetico-deductive framework Thus, theoretical framework and hypotheses are developed in advance of the data gathering process and the causal relationships are subsequently tested

The unit of analysis is NHVP industries in non-core regions The case of the micro-computer hardware industry in Ireland and Scotland is relevant to the topic The industry is considered a prime example of NHVP and Ireland and Scotland are traditionally considered as non-core regions At the same time, because of the characteristics of the components used, the industry can serve as a critical case in testing part of the theory

The theory and hypotheses concern the relation between NHVP and the extent of local linkages in non-core regions The hypothesis is not tested using traditional quantitative statistical methods Instead testing takes the form of matching the pattern of the *a priori* developed theory to the empirically based pattern The internal validity of the results is increased by the development of three rival hypotheses The methodology involves analytical generalisation, rather than statistical generalisation Thus, the results of the case study cannot be generalised to the population of NHVP industries Rather, theories about the geographical configuration of other NHVP industries are the target to which the results might be generalised However, this generalisation is not automatic but requires the replication of the findings in a second or even third NHVP industry Thus, apart from providing an explanation for the case of the microcomputer hardware industry, the present case study serves as one element in a broader academic process of cumulative theory formation

As regards data collection, interviews were the main source of evidence while a postal questionnaire, documentation and direct-observation were used as well All 11 main branded computer makers in Ireland and Scotland were selected for interview and all companies co-operated A range of staff members was interviewed in each company in three separate rounds All interviews were guided by semi-structured or structured questionnaires

Several strategies were adopted to support the validity and reliability of the results Validity was supported by the establishment of a chain of evidence, the development of *a priori* rival theories, triangulation, the use of rich data and quasi statistics The use of semi-structured and structured questionnaires and the development of a case study database facilitated reliability

CHAPTER 4 THE MICROCOMPUTER INDUSTRY IN IRELAND AND SCOTLAND AND NEW HIGH VOLUME PRODUCTION

4 1 Introduction

After defining the industry in section 4 2, section 4 3 provides an overview of the global microcomputer industry Section 4 4 introduces the microcomputer industry in Ireland and Scotland in the form of a brief history of the promotion and development of the industry The main part of the chapter, section 4 5, determines the extent to which the microcomputer industry matches the textbook picture of NHVP as outlined in section 2 3 The purpose of this section is to provide the necessary basis for analysing the geographical configuration of the supply network in Chapter 5 The conclusions follow in section 4 6

4 2 The Microcomputer Industry Defined

The term 'microcomputer industry' is an inheritance of the segmentation of computer hardware into mainframes, mini-computers and microcomputers, as it applied in the 1970s Recent developments and refinements in computing technology have removed part of this basic product distinction, but the term microcomputer continues to be used (Chandler, 1997, Dunlop and Young, 1989, Warnke, 1996) The first computers were all mainframes – very large powerful and expensive systems serving governmental and large industrial users The 1960s and 1970s saw the rise of the minicomputer These systems differed from mainframes mainly in terms of processing power and cost Developments in integrated circuit technology reduced the cost of processing power and brought the computers into the reach of more users The minicomputer served smaller firms or departments and was used for scientific, engineering and business tasks

The 1970s saw the rise of the microcomputer, creating a third segment in the industry The microprocessor technology combined central processing circuitry, different types of memory chips and input/output register on a single chip, providing "a computer on a chip" (Chandler, 1997) The cost of processing power was reduced significantly This made computers available to an even wider set of users Notably, microcomputer technology facilitated the development of PCs, including portables, laptops and notebooks Rather than single computers for entire enterprises or departments, PCs were smaller and less powerful systems, used by individuals

Rapid advancements in processing speed expanded the application of microcomputer technology At the end of the 1970s more powerful microcomputer technology started to be applied in systems for scientific, engineering, and industrial institutions – the workstations Thus, these workstations increasingly penetrated the market that the minicomputers were designed to serve, and this eventually led to the demise of the minicomputer Workstations can be further subdivided into traditional workstations and personal workstations Traditional workstations have long been associated with high performance computing using RISC-based processors and the Unix operating system Personal workstations were originally defined as the lower-end systems using Intel processors and Windows software However, the distinction between the two workstation categories and, indeed, between workstations and PCs is becoming blurred because of advancements in processing power and new hardware/software solutions, bridging the traditional categorisations Increasingly, the only way to determine a system as one or the other is based on actual use

At the end of the 1980s and increasingly during the 1990s microcomputer technology received yet another application Individual PCs and workstations were increasingly linked into networks of computers via central servers Initially minicomputers or mainframes performed the server functions However, advancements in microprocessor technology meant that specially designed microcomputers could act as servers as well These systems generally serve the low-end of the market In the classification used by

IDC, an international information technology research company, these servers are grouped under 'entry level servers' (costing less than $100,000 in 2001)

In this dissertation the microcomputer hardware industry is defined as the industry producing PCs, including laptops and notebooks, workstations and entry level servers

4 3 Global Geography of the Microcomputer Industry

At the start of the 1980s the overall computer industry could still be segmented into three major product groups mainframes, minicomputers and microcomputers (then mainly PCs) From the 1940s to the early 1980s, the mainframe market, dominated by USA based IBM, had been the most important segment although its share had been diminishing throughout the 1970s and early 1980s due to the increased popularity of minicomputers, manufactured by pioneering firms such as Digital Equipment Corporation The first PC (*Altair*) was produced for the hobby market in 1974 but it was not until 1977, with the launch of the Apple II, that it started to challenge the other two segments The market for PCs really took off in 1983 with the introduction of the IBM PC1 and by 1985, the market for PCs was already larger than the market for mainframes or minicomputers (O'Brien, 1986)

After its conception in the 1950s the computer industry was quickly dominated by companies that competed on a global scale At the end of the 1970s, the mainframe and minicomputer business was dominated by USA based companies that internationalised at an early stage of the product life cycle by establishing their own manufacturing facilities in the major world markets Thus USA based companies such as IBM, Burroughs, Honeywell, NRC, Hewlett Packard, Digital, Wang, Apollo, Prime, Concurrent, Amdahl and Stratus all operated manufacturing facilities in Europe as well as the USA A handful of European companies, notably Olivetti, ICL, Groupe Bull, Norsk Data and Nixdorf had a modest share of the world market, mainly based on strong positions in their home markets (O'Brien, 1988) Manufacturing operations of these European companies were typically located in the home nations

Like the mainframe and minicomputer industry, the PC industry has been dominated by USA based firms that competed on a global scale from an early stage [1] In 1984, the top 10 players in the United States market were all USA based companies Initially the market was shared amongst a group of relatively young pioneering companies, notably Apple Computers However, with the launch of the PC1 in 1983, IBM quickly dominated the market, thereby establishing the *de facto* world technical standard In 1984, IBM had 40 1 per cent of the US PC market (in value terms) while its nearest competitor, Apple, had 13 5 per cent Other important players included Tandy, Compaq, Hewlett Packard, Wang, Digital and Zenith European and Japanese companies had no significant presence in the US market, although Olivetti was supplying PCs on an OEM basis to AT&T, who had one per cent of the market (O'Brien, 1986)

Likewise the Western European market was dominated by USA based companies In 1984, IBM and Apple together were responsible for 46 per cent of the professional PC units sold Other USA based companies in the top 10 included Hewlett-Packard, DEC, Commodore, Tandy and Compaq The main European companies included Olivetti, with 7 8 per cent of the Western European market and ACT/Apricot with a 5 5 per cent share The other main European players involved in 1994 included Bull and SMT-Goupil (both French), Tiumph-Adler, Nixdorf and Siemens (all German), ICL (UK) and Philips (Dutch) In all, the European companies had approximately 25 per cent of the European market The only company with a significant position outside its home market was Olivetti, which had a moderate presence in most Western European countries as well as in the USA Apricot failed in its attempt to penetrate the US market

In 1984, the relatively small Japanese PC market was dominated by two Japanese companies producing propriety technology based systems NEC with 65 per cent of the market and Fujitsu with 15 per cent IBM had a relatively small share of 10 per cent, mainly due to technological difficulties related to the Japanese language Apple's share

[1] The following account of the PC business in the year 1994 is based on O'Brien (1986) Figures pertain to the professional PC segment only However, this segment accounted for 78 per cent of the overall PC market in 1984

was insignificant The Japanese companies had not managed to make a significant impact outside their home markets

Since the early 1980s, the microcomputer industry has undergone significant restructuring in the context of further globalisation In the PC segment, intensive competition on a global scale and the dominance of the IBM *de facto* industry standard resulted in a shake-out of some of the first players, particularly those that had attempted to compete with proprietary technologies, and the rise of new clone manufacturers In the growing market for workstations, that became increasingly difficult to separate from the PC market, new start-up companies were able to quickly establish a strong global presence as well

USA based companies continued dominating the industry although the names have changed Over the 1980s and 1990s, a number of new USA based clone manufacturers, such as Compaq, Dell, Gateway, Packard Bell and AST, gained an impressive share of the global market for PCs and eventually overtook the stars of the early 1980s Other players lost much of their market share (IBM Apple, and Hewlett Packard) and some withdrew from the PC market all together, often due to the inability to compete with proprietary technology Thus, at the end of the 1980s Wang exited the PC market and Zenith sold its PC business to Bull (Wells and Cooke, 1992) AST purchased Tandy in 1993 Fierce competition in the second half of the 1990s led to loss of market share of both long established companies and new clone manufacturers Digital, which had never been very successful in penetrating the PC market, was eventually taken over by Compaq in 1998 (O'Sullivan, 1998) AST was taken over by Samsung in 1997 (Casey, 1997a) while NEC took control of Packard Bell in 1999 (Price, 1999) Gateway was forced to retreat to its home market in 2001 (Smyth, 2001)

A small number of USA based companies increasingly dominated the global market for technical workstations In 1988, four USA based firms, Sun Microsystems, Digital, Hewlett Packard and Apollo already controlled 77 per cent of the global market The dominance of Sun Microsystems, a young start-up company, lead to further consolidation with Hewlett Packard taking over Apollo by the end of the decade (Wells and Cooke, 1992)

European companies lost most of the market share they had in the early 1980s, even in their home markets, largely due to a failure to establish the international presence required to compete in this business (O'Brien, 1986) UK based Amstrad was able to build up a ten per cent share of the European PC market in the second half of the 1980s but was unable to hold on to it Olivetti, the other pan-European player, failed to consolidate its market share and exited the PC hardware market in 1998 (*Financial Times*, 04-03-98) Apricot, who had been unsuccessful in its attempts to grow outside its home market, was taken over by Mitsubishi in 1990 Apricot continued to exist as a legal entity within Mitsubishi but kept losing market share and eventually retreated from the PC market in 1999 Groupe Bull attempted to break into the global PC market with the purchase of Zenith in 1989 (Wells and Cooke, 1992) but was not successful and sold Zenith to Packard Bell in 1996 In 1998, Tulip Computers, one of Europe's last major independent PC makers went into receivership (*The Irish Times*, 01-05-98) In the late 1990s, the only European company with a significant PC business was Siemens-Nixdorf However, Siemens had been searching for a partner to enter the US and Asian markets This it found in Fujitsu and in 1999 the European computer operations became part of the joint-venture company Fujitsu-Siemens Computers (Lyons, 1999b)

During the second half of the 1980s Japanese companies continued to prosper in a relatively protected home market but adopted aggressive globalisation strategies in the 1990s (Wells and Cooke, 1992) Mitsubishi took over Apricot in 1990 Fujitsu acquired ICL in 1991 (Morgan, 1991) and set up the joint venture with Siemens in 1999 NEC took a share in Packard Bell in the early 1990s before taking control of Packard Bell and Zenith in 1999 As a result, companies like NEC, Fujitsu and Toshiba acquired an important share of the world microcomputer market, largely based on their strength in the portable segment Finally, South Korean and Taiwanese companies such as Samsung, Lucky Goldstar, Acer and Mitac quickly established themselves as important suppliers of microcomputers on an OEM basis A number of these companies, notably Samsung and

Acer, started to sell computers under there own name and gained a significant share of the microcomputer market As part of its globalisation drive Samsung took over AST in two stages during the period 1997-98 (Taylor, 1998)

Tables 4 1 and 4 2 present the market share of the top 10 companies in the various segments of the microcomputer industry at the time the first interviews of this study were carried out USA based companies clearly dominated the PC segment Six USA based companies appeared in the top ten of world-wide PC shipments with a combined share of just over 45 per cent Three Japanese companies, NEC, Toshiba and Fujitsu had approximately 13 per cent of the market Siemens was the only European company in the top ten, with a very modest market share The world-wide market for workstations was virtually totally controlled by USA based companies with the top four companies holding a combined share of over 80 per cent of the personal workstation market while the top four companies in traditional workstations held 95 per cent of the market Similarly, the world-wide market for entry level servers was dominated by USA based companies, with the top four companies holding 60 per cent of the market The only European company in the top 10, Siemens, held two per cent of the market The picture for the Western European market was very similar Siemens had a somewhat more prominent position in the PC and entry level server segments but both segments were dominated by USA based companies Five USA based companies again accounted for over 45 per cent of the PC market while the top four USA based companies held 70 per cent of the server market

As was the case in the mainframe and minicomputer industry, the main microcomputer players typically supported their global competition strategies with a global manufacturing presence Success in the microcomputer industry required companies to compete on a global scale and global competition required a multiregional presence Thus, one of the pioneers in the PC hardware market, Apple, established its European manufacturing facilities as early as 1980, while IBM started manufacturing and developing PCs in Europe in 1983 (IBM, 1991) In 1989, nine out of ten PCs sold in Europe – mainly by USA based companies – were being manufactured by firms with a European Community presence (Dunlop and Young, 1989)

Table 4 1 Share of world-wide microcomputer shipments (units) by vendor,1998

PCs		Personal w'stations		Traditional w'stations		Entry level servers (<$100,000)	
Compaq	14 4%	HP	38%	Sun	57%	Compaq**	25%
IBM	8 7%	Dell	17%	HP	17%	IBM	14%
Dell	8 5%	Compaq**	14%	IBM	12%	HP	13%
P Bell-NEC*	6 5%	IBM	12%	SGI	10%	Dell	8%
HP	6 2%	Intergraph	3%	Digital	5%	Sun	4%
Fuj Siemens*	5 3%	Digital**	2%			Digital**	2%
Gateway	3 9%	Other	14%			Siemens	2%
Toshiba	3 4%					P Bell-NEC*	2%
Apple	3 4%					Fujitsu	2%
Acer	3 0%					Acer	2%
Others	36 7%					Other	26%

Source IDC, November and December 2001

Note * The joint-venture between Fujitsu and Siemens was only set-up in 1999 while NEC only acquired a controlling share in Packard Bell in 1999 However, IDC only provided combined figures

** Digital and Compaq counted separately until Q2 1998

Table 4 2 Share of European microcomputer shipments (units) by vendor, 1998

PCs		Personal w'stations		Traditional W'stations		Entry level servers (<$100,000)	
Compaq	18 2%	HP	42%	Sun	46%	Compaq**	24%
Fuj Siemens*	11 3%	Compaq**	24%	HP	18%	IBM	22%
IBM	9 1%	Dell	16%	IBM	18%	HP	14%
Dell	8 4%	IBM	11%	SGI	12%	Sun	10%
HP	6 9%	Intergraph	4%	Other	7%	Siemens	8%
P Bell-NEC*	5 2%	Digital**	3%			Dell	5%
Vobis	4 3%					Digital**	4%
Toshiba	3 8%					Groupe Bull	3%
Acer	2 8%					Fujitsu	1%
Apple	2 8%					Data General	1%
Others	27 3%					Others	8%

Source IDC, November and December 2001

Note * The joint-venture between Fujitsu and Siemens was only set-up in 1999 while NEC only acquired a controlling share in Packard Bell in 1999 However, IDC only provided combined figures In the first half of 1999, Fujitsu had a market share of 6 6 per cent while Siemens' share was six per cent This means that they probably occupied fifth and sixth position in Europe (*De Telegraaf*, 18-06-99)

** Digital and Compaq counted separately until Q2 1998

At the time the first interviews were carried out, in 1998, nearly all companies that co-operated in the present study had at least one microcomputer assembly and test facility to serve each of the triad regions North America, Europe and the Far East The exceptions were Sun that used its European facilities to cover the Far Eastern markets and lagging Apricot-Mitsubishi, that had no manufacturing presence in the USA All plants were manufacturing the entire range of microcomputers that the company offered although there was some intra-company specialisation among plants in the USA, while the single most advanced servers were typically manufactured in the USA only A number of companies had recently invested in Brazil to cover the South-American market and three companies operated small software configuration centres in Australia Sections 4 5 1 and 4 5 4 will look more closely at the forces that shaped this geographical configuration of assembly facilities

Within Europe, Ireland and Scotland were clearly a preferred base for microcomputer production in 1998 Out of the world-wide top ten Compaq, Digital, IBM, Dell, Packard Bell-NEC, Gateway, Apple and SUN all had a manufacturing base in either Ireland or Scotland Of the other players in the top ten, Siemens assembled microcomputers in Augsburg, Germany and Hewlett Packard in France and Germany (Ryan, 1996)

4 4 Promotion and Development of the Microcomputer Industry in Ireland and Scotland

This section introduces the microcomputer industry in Ireland and Scotland The first sub-section describes the promotion activities and development of the industry in Ireland The second sub-section deals with the Scottish microcomputer industry Particular attention is paid to the issue of industrial linkage formation

4 4 1 Ireland

The discussion of the development of the microcomputer industry in Ireland is supported by data from the annual Irish Economy Expenditure (IEE) survey carried out by the IDA Ireland (since 1998 carried out by Forfas) The survey contains questions on employment, sales, exports and expenditure on Irish raw materials For the purpose of this research, data on the computer assembly companies that operated in Ireland over the last 25 years[2] were extracted and the results are presented in Table 4 3 The data should be treated with caution, since they have been grossed up from small samples Data on individual years might not include all companies Furthermore, the data did not include information on Intel's European Site for System Manufacturing, which operated in Ireland from 1990-1998 and had a peak employment of 1,500, since it was not possible to separate data on this plant from data on the wider Intel operations However the data do give a helpful overview of the growth of the computer assembly industry in Ireland Table 4 4 outlines the succession of plant openings and closures by the main computer assemblers in Ireland

Ireland has been a relative latecomer as regards industrial development After a protectionist period that lasted until 1958, the Irish government adopted a new economic and industrial development model based on outward-looking policies such as free trade, the encouragement of exports and inward foreign direct investment (O'Malley, 1989) In the 1970s, the Industrial Development Authority (IDA) set out with a very successful focussed strategy of searching out emerging growth sectors and their star companies and targeting them via an aggressive direct marketing approach (MacSharry and White, 2000) One reason for targeting the star companies was that investment decisions by such companies were believed to have a strong demonstration effect on other companies In 1971 one of the first major successes of the direct marketing approach was the decision by Digital Equipment Corporation, one of the pioneers in the minicomputer industry, to set up a large-scale minicomputer manufacturing plant in Ireland Digital's presence had a strong demonstration effect heavily influencing the decision of many major multinational computer hardware and software companies to locate in Ireland in later years

In the second half of the 1970s the IDA specifically identified electronics and computers as a target sector and a number of sub-sectors were considered relatively stable and less dependent on low-cost labour minicomputers, computer peripherals, specialist

[2] Included in the analysis were Digital, Concurrent, Prime, Stratus, Nixdorf, Computer Automation, Amdahl, Apple, Zenith, Wang, Dell, AST and Gateway Intel (ESSM) was not included in the data

components ıncludıng ıntegrated cırcuıts, ınstruments, process control equıpment, busıness electronıcs, subassemblıes to the above (Hanna, 1984) The focussed targetıng strategy became very successful ın the latter half of the 1970s when four other mınıcomputer companıes – Prıme, Nıxdorf, Computer Automatıon and Concurrent – set up assembly facılıtıes ın Ireland, whıle Amdahl started assemblıng maınframes The companıes were attracted by a ten per cent corporate tax rate, relatıvely low wages, ınvestment ın a new state-of-the-art telecommunıcatıon system and an ıncreasıng number of electrıcal engıneerıng graduates as a consequence of a brısk response by the Irısh educatıon system (MacSharry and Whıte, 2000)

Table 4 3 Key growth ındıcators computer assembly sector* ın Ireland, 1980-1999

Year	Total employment**	Sales (£bn)***	Exports (£bn)***	Irısh raw materıals as Percentage of total***
1980	2,140			
1981	2,419			
1982	2,585			
1983	2 901	1 1	1 1	5 8%
1984	3,008	1 3	1 3	5 5%
1985	3,082	1 7	1 7	5 1%
1986	3,344	1 6	1 6	6 0%
1987	3,742	2 0	2 0	5 2%
1988	3,924	2 1	2 1	7 2%
1989	4,030	2 7	2 7	5 0%
1990	3 426	2 3	2 2	11 1%
1991	3,259	1 6	1 6	13 4%
1992	3,359	1 9	1 8	17 1%
1993	3,487	2 1	2 1	20 2%
1994	3,757	2 4	2 3	24 5%
1995	4,752	3 1	3 0	27 0%
1996	5,601	3 0	2 9	21 1%
1997	6 195	3 7	3 6	26 3%
1998	6 719	4 4	4 1	28 0%
1999	6,569	6 7	6 4	27 6%

Notes

*Included ın analysıs Dıgıtal, Concurrent, Prıme, Stratus, Nıxdorf, Computer Automatıon, Amdahl, Apple, Zenıth, Wang, Dell, AST and Gateway Intel (ESSM) only ıncluded ın employment figures, based on own estımate (see text)

**Estımates for Intel ESSM ıncluded on the basıs of employment growth of 200 per year from 1990 to a maxımum of 1,500 ın 1997

***Excludıng Intel ESSM

Source Irısh Economy Expendıture Survey, Forfas

Table 4.4 Main computer assemblers in Ireland, 1970-2002

	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02
Digital																																	
Concurrent																																	
Prime																																	
Stratus																																	
Nixdorf																																	
Comp Autom																																	
Amdahl																																	
Apple																																	
Zenith																																	
Wang																																	
Intel																																	
Dell																																	
AST																																	
Gateway																																	
Horman (APW)																							n d							n d			
IBM																																	

Source see text
Key
Dark shaded cells indicate the years a company was involved in computer assembly
Light shaded cells indicate the years a company operated in Ireland but was not assembling computers
n d = no data

Although successful in attracting a large number of computer and electronics firms to Ireland, the level of local embeddedness was limited Typically the Irish operations were limited to assembly only and the firms created limited linkages in the Irish economy During the 1970s a number of foreign computer component and peripheral companies had invested in Ireland For example Mostec, Memory and Data Products were producing memory products, printers were being manufactured by Centronics, Storage Tech and Data Products and Molex assembled cables and interconnect material (Interview Hanna, IDA, Dec 2001) However during the 1970s MNEs hesitated bringing suppliers over to Ireland because they did not want the companies to be dependent on them Companies were flying in everything, including bulky items such as metal casings (Interview Kennedy, Forbairt-NLP, Oct 1996) In 1983, the IEE survey carried out by the IDA showed that the computer assemblers sourced only 6 per cent of their material inputs from suppliers located in Ireland

The success of the 1970s was interrupted by the economic crisis of the first half of the 1980s Compounding the crisis was a shrinking market for minicomputers due to the increasing popularity of the PC As a result, most of the minicomputer assemblers that had been attracted in the late 1970s closed their Irish plants in the first half of the 1980s Between 1982 and 1985, Concurrent, Prime and Computer Automation all closed their Irish manufacturing operations while Nixdorf would follow in 1989 Component manufacturers were closing as well, e g Mostek in 1985 (MacSharry and White, 2000)

In 1984, a complete policy rethink within the IDA led to a new focus on attracting industries that could achieve high output growth using the best technology available, while maximising their spend in the Irish economy, even if these industries were not the most labour-intensive Apart from tax incentives and access to the common market, an educated labour force, rather than low wage rates, was to become one of the main marketing factors The electronics industry was believed to live up to the criteria (MacSharry and White, 2000) However within electronics, minicomputers were replaced by PCs as a sub-target sector

The first microcomputer assemblers in Ireland were Apple and Wang who started manufacturing PCs in 1980 As the pioneer of the PC, Apple's investment decision had a major demonstration effect within the electronics industry and in 1983 Zenith followed with another PC assembly facility However, the crisis of the early 1980s meant that the real effect was not felt until the late 1980s and early 1990s With the economic recovery after 1987 the IDA strategy of focussed targeting of high-tech, high output, companies and industries started to bear fruits, particularly after 1989 when a number of prestigious high-technology companies decided to invest in Ireland, a decision made possible by the continued output of graduate engineers The real breakthrough came in 1989 with the decision of Intel to invest in a sophisticated microprocessor wafer manufacturing plant as well as a PC and motherboard assembly plant

The presence of Intel had a strong demonstration effect and a large number of computer related companies followed in the early 1990s As to the microcomputer assemblers, initially Wang and Zenith were out-competed and finally closed their Irish facilities in 1991, while Digital, that had started assembling PCs in Ireland, decided to consolidate its assembly operations in Scotland, resulting in the closure of the Irish assembly plants in 1993 However, these losses were more than offset by the investment of three new PC assemblers, Dell, Gateway and AST, while an indigenous subcontractor, Horman Electronics (later acquired by USA based APW), diversified its activities with full system assembly for Apple

As part of the policy rethink of the mid-1980s, in an effort to increase the attractiveness of Ireland for foreign MNEs, and at the same time increase their local embeddedness and spend in the Irish economy, the IDA aimed to upgrade the local supply structure One way was through the attraction of foreign component suppliers, some of which were part of other targeted sub-sectors of the electronics industry anyway "The IDA electronics division used a see-through model of a computer to identify every component in it Then, systematically, it canvassed the makers of each individual component, such as keyboards, hard disks, cables, computer mice and sub-assemblies" (MacSharry and White, 2000, p 288) Additionally, the National Linkage Programme (NLP) was set up in 1985 with the objective of significantly increasing the proportion of sub-supply materials purchased by MNEs from indigenous Irish companies or smaller foreign companies located in Ireland Activities involved highlighting linkage opportunities, developing the technical and management expertise of the suppliers and encouraging a strong support link between the buyer and supplier companies (DKM, 1993, Kelly, 1988)

However, the proportion of material inputs sourced from the Irish economy, particularly from Irish indigenous companies, remained disappointing In early 1993, against the background of the closure of the manufacturing plants of Nixdorf, Zenith, Wang and Digital, one industry observer stated that electronics firms in Ireland were isolated from each other and from the local economy "Rather than constituting an industry, they are a series of isolated units that just happen to be based in Ireland" (Wickham, quoted in Cullen, 1993) The problem of limited linkage formation had been highlighted in the report of the Industrial Policy Review Group in 1992 (IPRG, 1992) The report called for a greater integration of MNEs into the Irish economy in terms of linkages, the promotion of industrial clusters and a more decisive shift in the focus of policy towards developing indigenous industry Towards this, in 1994, the IDA was split into two divisions One, the new IDA, was to specialise on foreign direct investment and the second, Forbairt (since 1998 Enterprise Ireland) was to concentrate on indigenous industry The NLP, as part of Forbairt, came up with a set of new initiatives to increase the linkages between MNEs and the local economy, including a Supplier Development Programme, a Tooling Support Programme, and Information Brokerage Service (McCall, 1997)

In reality, the efforts of the NLP were already having some success in the early 1990s An increasing number of indigenous companies were supplying the microcomputer assemblers with metal and plastic enclosures, printed material, packaging, cables and supply-chain services Furthermore, the IDA was attracting an increasing number of foreign companies manufacturing a range of material inputs such as keyboards, mice, hard disk drives, power supplies, PCBs, media, floppy disks, network cards and motherboards, as well as software producers – notably Microsoft – feeding a perception of the development of an integrated PC cluster (Carey, 1996, Casey, 1995, Casey, 1997b, Trench, 1995)

According to the IEE survey in 1993 computer assemblers sourced 20 per cent of their material inputs in Ireland, up from 11 per cent in 1990 Since then the figure rose further to 27 per cent in 1995 and 28 per cent in 1998 (see Table 4 3) In 1995, the manager of the NLP predicted that the Irish content of PCs produced in Ireland would rise to 40 per cent (Casey, 1995) However, these figures need to be treated with caution Firstly, the local content figures are characterised by strong fluctuations For example, before rising to 28 per cent in 1998, the figure dropped to 21 per cent in 1996 [3] Furthermore, a comparison with the figures obtained during the company interviews (see section 5 2 24) makes clear that the IEE figures strongly overestimate local sourcing in the industry The most likely explanation for this is that the IEE figures include items bought from local turnkey supply-chain-managers but manufactured in other regions

In fact, during the second half of the 1990s, rising wage rates in Ireland meant that certain sub-sectors of the electronics industry in Ireland came under severe competitive pressure from low cost locations in the Far East While continuing to attract a large number of high-tech, high output, manufacturing and service projects, Ireland witnessed an exodus of low-tech input manufacturers At one stage roughly 90 per cent of the mice sold in Europe were manufactured in Ireland (Carey, 1996) but that stopped with the closure of the Logitech plant in 1995 (O'Kane, 1995) In a period of two years, keyboard manufacturers Keytronics (O'Kane, 1996), Alps (Hogan, 1998) and Mitsumi (*The Irish Independent*, 08-01-98), ceased actual manufacturing of keyboards and continued as distribution operations, retaining only a limited localisation capability Plastic component manufacturer Acco closed in 1998 (Clifford, 1998) Seagate closed its hard disk drive facility in 1997, Western Digital had already pulled out in 1992 Disk component supplier

[3] These figures are roughly in line with earlier IEE analyses Thus, earlier studies found that companies in the somewhat broader sub-sector 'computers' sourced 19 per cent of their material inputs from Ireland, up from 14 per cent in 1992, and by 1995 the local content figure had risen to 27 per cent (Crowley, 1996, Gorg and Ruane, 1998) Here too, the figures show strong fluctuations For example, before rising to 27 per cent in 1995, the local content figure first dropped to 14 per cent in 1994

Applied Magnetics closed in 1998 (Casey, 1998) Also in 1998, Intel shifted its motherboard assembly activities from Ireland to the Far East

The IDA started to actively discourage large companies from siting certain manufacturing operations in Ireland where the main attraction was a lower cost base (Carey, 1996) In its 1996 review the IDA decided to drop the sub-sector 'peripherals and media' as a key target sector and, within the sub-sector 'computer systems', to focus on server manufacturing Other sub-sectors to be targeted included software development, contract manufacturing and computer networking/ data-communication (Ryan, 1996) Furthermore, the IDA started to work towards an increased embeddedness of the electronics industry by persuading companies to establish a range of value added activities in addition to manufacturing, i e research and development, software development, sales and technical support call centres, e-commerce and shared services (Interview Hanna, IDA ICT division, Dec 2001)

At the time this research project started, in 1998, Ireland had a sizeable microcomputer hardware industry (see Table 4 5) Four large branded microcomputer makers, Dell, Gateway, Apple and AST, operated assembly plants in Ireland while Intel operated the European Site for System Manufacturing (ESSM) to support its OEM business Finally, Horman Electronics assembled systems for Apple on a subcontracting basis The manufacturing activities of most companies were restricted to the final assembly and test of PCs and low-end servers Intel ESSM also assembled motherboards, partly for internal use Most operations included a range of other functions, such as sales and technical support call centres, European logistics centres and regional headquarters Based on the interview data, the five foreign companies together employed just under 9,000 permanent staff (FTE) while at peak periods the head count could rise well above this figure (see section 4 5 3) The computer assembly sub-sector (excluding Intel ESSM) had sales of IR£4 4bn, nearly all in export According to the IDA's own calculations, 33 per cent of PCs sold in Europe in 1999 were manufactured in Ireland (IDA promotional material quoted in Brennan, 2001)

Table 4 5 Activities of main microcomputer assemblers in Ireland, 1998

Company	*Activities in Ireland*	*Permanent employees (FTE)*
Apple	HQ Europe Middle-East and Africa (EMEA) PC assembly Motherboard assembly (stopped Q3 1998) Operating system and application software development and test European logistics centre	1,200 (Q4 1998)
Dell	PC and low-end server assembly (Limerick) European Product Group (140 staff in Limerick involved in product and process development) European logistics centre (Limerick) Sales and technical support call centre (Bray) HQ sales and marketing home and small business (Bray)	4,200
Gateway	HQ EMEA PC and low-end server assembly (complete range) European logistics centre Sales and technical support call centre	1,800
Intel (ESSM)	PC and low-end server and motherboard assembly (closed Q2 1998)	1,500
AST-Samsung	PC and low-end server assembly (since Q2 1998 only laptops) Motherboard repair and test centre European logistics centre Technical support call centre	450 (200 since Q2 1998)
Horman	Low-end PC assembly for Apple	Less than 200 (assembly only)

Source company interviews and newspaper articles

4 4 2 Scotland

Unlike Ireland, Scotland has a long and rich industrial history, initially dominated by shipbuilding, engineering, textile and beverages However, the decline of the metalworking and textile industries brought high unemployment and the need for economic restructuring FDI became an important vehicle towards this end The efforts to attract FDI were rather fragmented (SDA, 1979) until the establishment of Locate in Scotland, a joint-venture between the Scottish Development Agency (SDA) and The Scottish Office in 1981

The main marketing tools in attracting FDI to Scotland, included access to the UK and, since 1973, the European market, relatively low wage rates and financial and fiscal incentives (McCalman, 1988) – although the fiscal incentives were not nearly as attractive as those in Ireland The importance of the local market got an extra dimension with the important UK public purchases that allegedly were made conditional on the location of new investment projects within the UK (MacSharry and White, 2000), although these allegations have always been denied by the SDA

The electronics industry was targeted from an early stage, although this was as much a result of opportunity as strategy In an effort to tackle unemployment, the SDA simply went after all industries with a high propensity for foreign direct investment, which from the 1960s onward increasingly included electronics (Interview, Togneri, Scottish Development International, Dec 2001) Within the electronics industry, the SDA successfully targeted a wide range of sub-sectors, notably defence electronics, industrial and commercial electronics, information systems and semiconductors By the end of the 1970s the data processing industry was amongst the three most important 'area of attack' as regards inward investment (LIS, 1983, SDA, 1979)

Table 4 6 outlines the history of the computer assembly industry in Scotland The roots of the microcomputer industry in Scotland go back to the late 1940s and early 1950s In this post-war period Scotland attracted a substantial number of large USA based companies involved in the manufacture of electromechanical products, such as IBM, NCR, Timex, Burroughs and Honeywell Most of the plants later responded to changing markets and diversified into electronics products, with varying degrees of success IBM assembled its first mainframe computer in Scotland in 1959 Honeywell followed in 1964, producing mainframes at its Newhouse facility The Scottish facilities of NCR and Burroughs only diversified into computer assembly in the 1970s and 1980s, although the NCR plants in Scotland had been involved in computer component production since the 1950s (Interview Adamson, NCR, December 2001) With the rise of the minicomputer during the 1970s, the Scottish computer industry received a further impetus by Digital's decision in 1976 to expand its European production capability with a system assembly plant in Ayr

Table 4 6 Main computer assemblers in Scotland, 1950-2002

	40s	50s	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02
IBM																																													
NCR																																													
Timex																																													
Burroughs																																													
Honeywell																																													
Bull/NEC																																													
Digital																																													
Compaq																																													
Sun																																													
Apollo																																													
Apricot																																													
Wang																																													
GPT																		no data																											
Tandem																																													
P B -NEC																																													
Inventec																																													
Fullarton																																													

Source see text

Key

Dark shaded cells indicate the years a company was involved in computer assembly

Light shaded cells indicate the years a company operated in Scotland but was not assembling computers

Although successful in attracting a great number of, particularly USA-owned, computer assemblers and other electronic hardware projects in the 1960s and 1970s, their indirect developmental effect through local linkage creation was disappointing Data on the computer industry as such do not exist but there are data on the electronics industry and by the end of the 1970s the computer assembly industry made up an important part of the electronics industry (McCalman, 1988) An SDA study of the electronics industry in Scotland showed that in 1979 packaging and printed circuit boards were the only supplies sourced primarily in Scotland The sourcing of metal products was divided equally between Scotland and England (SDA, 1979) Data from the Industry Department for Scotland show that by 1979, electronics companies sourced only 10 per cent of their commodity purchases in Scotland On the other hand, a sizeable 52 per cent of total commodity purchases was sourced in the rest of the UK (Turok, 1997)

In 1979 the SDA responded with a strategy to strengthen the supplier base, either through the stimulation of indigenous enterprise or inward investment (SDA, 1979) Initially, the stimulation of inward investment by foreign supply companies raised concern regarding the displacement effects on local enterprises although Locate in Scotland claimed to operate on the basis of additionality Concerns to avoid such effects were largely abandoned during the 1980s The reasoning for the 'gap-filling' strategy was that "the strong base of equipment firms attracts suppliers, whereas the strengthening of the supply chain is an incentive for further inward investment by equipment manufacturers" (Clarke and Beany, 1993, p 223) Where the perception was that gaps could be filled by indigenous companies, the companies could benefit from the SDA Business Development Programme In addition the SDA provided equity investment where gaps in the supply chain could be filled by assisting start-ups Other activities included marketing support and intelligence

The rise of the PC and workstation market during the 1980s, led to a new wave of restructuring involving new investments as well as major downsizings and job losses IBM dedicated a large part of its manufacturing space to the production of PCs making the Scottish operations the centre for personal systems in Europe - a major milestone for the development of the PC industry in Scotland Digital invested in a new PC assembly plant in Irvine in 1984 and later started workstation assembly in Ayr During the 1980s, both companies operated fairly integrated manufacturing operations producing systems as well as components, peripherals and, in the case of IBM, monitors In 1990, Digital even set up a facility to manufacture microprocessors that were packaged in the Ayr facility and subsequently formed an input for the system assembly lines The NCR facilities in Dundee increasingly focussed on ATM systems

Other existing computer plants were lost After more than twenty years of computer assembly, Honeywell stopped producing mainframe and business computers in the second half of the 1980s and focussed its Scottish manufacturing operations on heating control systems The global computer division was sold to Company Bull who continued the production of Honeywell-Bull branded mainframes and minicomputers in rented space at the Newhouse facility during the rest of the 1980s, before moving to the old Apollo facility in the early 1990s (see below) In 1986, the Burroughs plant closed after rationalisation following the merger between Burroughs and Sperry Univac The Timex plant attempted to diversify away from watch production and from 1981 to 1983 produced PCs for Sinclair but the plant eventually closed following a severe industrial dispute Similarly, in its attempt to diversify its telecommunication activities, GPT assembled PCs on a subcontracting basis for UK based Amstrad from 1985 to 1988 At the end of the 1980s, Amstrad had planned to acquire the GPT facility to produce PCs (Clarke and Beany, 1993) but these plans never developed and the plant eventually closed in the early 1990s

New arrivals during the 1980s included PC assemblers such as Wang (1982), Compaq (1987) and Birmingham based Apricot, (1983) as well as two USA based workstation assemblers, Apollo (1986) and Sun (1989) The Scottish success in attracting three of the main workstation producers might be partly related to the weight of public purchases in this sector and the size of the UK market (Interview, Hanna, IDA December 2001) Some of the new arrivals had gone again by the end of the decade Wang was unsuccessful in its attempt to switch from word processors to general purpose PCs and closed its Stirling plant in 1988 The Apollo plant in Livingston closed in the context of a rationalisation programme following the take-over by Hewlett Packard in 1990 (Clarke and Beany, 1993)

The first half of the 1990s was relatively quiet as regards investments in new computer assembly ventures in Scotland USA based Tandem started producing large fault tolerant systems in the old Wang facility in 1993 while the Bull NEC venture, that had moved from Newhouse to the vacated Apollo facility in Livingston in 1990 to produce minicomputers and PCs, stopped assembling computers in 1993, concentrating instead on system configuration and software development The second half saw a new wave of consolidation and restructuring in the computer industry in Scotland IBM outsourced low-end computer assembly to indigenous enclosure manufacturer Mimtec (taken over by Fullarton in 1997) and in 1997 Taiwanese Inventech invested in a new assembly facility to assemble low-end systems for Compaq In the same year, Tandem was acquired by Compaq and production was shifted to Compaq's main plant in Erskine One year later Digital merged with Compaq leading to an integration of the production facilities in Scotland and the closure of the Digital's PC assembly facility in Irvine (Lyons, 1998b) Also in 1998, Packard Bell-NEC started assembling PCs in the plant vacated by the Bull/NEC partnership

As regards local linkage creation, the SDA aim of strengthening the local supplier base in the 1980s did have some success Power supplies were identified as a potential area for 'gap filling' and the SDA supported the start up of a new Scottish company, Domain Power, which was quickly acquired by US Switchcraft and later became part of the Japanese Minebea group By the end of the 1980s the sector was strengthened by the decision of Taiwanese Delta Electronics to establish a plant to supply Compaq (Clarke and Beany, 1993) Another area for gap filling was disk drives In 1981 the SDA supported the start up of an indigenous company called Rodime, set up by former employees of Burroughs that until then had been producing hard disk drives in Scotland The SDA later attracted Conner Peripherals and YE Data USA-owned Eeco opened a keyboard manufacturing plant In the second half of the 1980s, the gap in PCB assembly was filled through the inward investment by USA-owned companies such as SCI, AVEX and Solectron Also during the 1980s, indigenous companies such as Mimtec, Fullarton, Simclar and Turnkey captured an increasing share of the enclosure and general subcontracting services business (Turok, 1993)

However, in spite of the expansion of the suppliers base, there is no evidence of a significant increase in the proportion of material inputs sourced in Scotland Surveys of electronics companies carried out in 1984 (McCalman, 1988), 1986, 1988, 1990 and 1991 (Turok, 1993) all come up with a figure between 12 and 15 per cent, although the figure for computer companies was probably slightly higher – the 1984 survey by McCalman showed that the eight computer assemblers in the sample of 30 electronics firms sourced 21 per cent of their inputs (excluding purchases from parent organisations) in Scotland Apparently, rather than catching up, the growth of supplier companies in Scotland was almost in proportion to the growth in output of the customer companies located in Scotland A survey amongst 13 of the largest foreign electronics companies in Scotland (including all the major computer assemblers) carried out in 1991, showed that the highest levels of local sourcing were found in 'low-tech' component categories such as keyboards, plastics, cables, metal, packaging and printed material The sample companies sourced only 18 per cent of their PCB requirements in Scotland and more sophisticated, higher value, components such as disk drives, monitors, power supplies, microprocessors, capacitors and resistors were almost completely imported (Turok, 1993)

Like in Ireland, many of the local linkages created in the 1980s ceased in the first half of the 1990s For example, Rodime went bankrupt in 1991 (Turok, 1993) Conner Peripherals and YE data closed Delta stopped the manufacture of power supplies Minebea/NMB did as well and concentrated on keyboard localisation Eeco closed its keyboard operations A small number of new supply companies invested in Scotland, notably USA based Jabil that set up a PCB assembly facility in 1993 In 1997, Lite-on invested in a monitor assembly plant to supply IBM but the company withdrew less than one year later, under pressure of the Asian financial crisis (James, 1998) The reduction in local linkages is reflected in the annual Scottish Enterprise survey (formerly carried out by the SDA) of the 16 largest foreign owned electronics companies (including all the main computer assemblers) As a proportion of total purchases (excluding electronic components, inter-company trading and services), local sourcing had come down from 27 per cent in 1992 to 21 per cent in 1995 (Turok, 1997)

At the time this study started, in 1998, like Ireland, Scotland had a sizeable microcomputer hardware sector dominated by foreign MNEs (see Table 4 7) Six of the main global branded microcomputer makers, IBM, Compaq, Digital, Packard Bell-NEC, SUN and Apricot-Mitsubishi operated system assembly plants in Scotland while two companies, Fullarton Computers and Inventec were involved in system assembly on a subcontracting basis Compared to Ireland, to some extent the companies were manufacturing higher-end products Four companies were assembling low-end PC and server models only but four other companies were assembling higher-end servers, workstations, storage systems and larger fault tolerant computers as well Furthermore, four companies were assembling limited amounts of server boards on site A number of operations included a range of other functions The IBM and Digital sites both housed call centres for technical support and central order desks as well as system development groups while the Sun operations included the HQ for Europe Middle East and Africa The eight companies together employed just under 9,000 permanent staff (excluding the non-system assembly activities of Fullarton) while at peak periods the head count could rise well above this figure (see section 4 5 3) According to the calculations of the SDA (now Scottish Enterprise), in 1997 Scotland produced almost 37 percent of the branded PCs sold in Europe, 68 percent of electronic notebooks, 60 percent of Europe's workstations and 16 percent of its computer peripherals (Carding, 1997)

Local linkage creation had remained a prominent issue in the SDA strategy during the 1990s "The main challenges to be addressed are to strengthen the links between foreign owned companies and within sectors Such linkages are weak and the Scottish economy is fragmented as a result" (Scottish Enterprise 1994, quoted in Turok, 1997)

Table 4 7 Activities of main microcomputer assemblers in Scotland, 1998

Company	*Activities in Scotland*	*Permanent employees (FTE)*
Compaq	PC, server, workstation and fault tolerant computer assembly Motherboard assembly for high-end server models	2,000
Digital (merged with Compaq 1998)	High-end server, workstation, storage system and PC assembly (PC assembly stopped Q4 1998) Motherboard assembly for servers Order fulfilment centre Call centre (central order desk and order related technical support) Development group for special systems 'CSS' (14 heads)	800 (down from 1,300 before closure of PC plant Q4 1998)
Apricot-Mitsubishi	PC and server assembly for world markets Motherboard assembly (stopped January 1999)	220
Sun	HQ EMEA Workstation, high-end server, fault tolerant computer and storage system assembly	750
IBM	High-end PC, low-end and high-end server and workstation assembly Motherboard assembly for servers Technical support call centre and central order desk European logistics centre R&D group for servers and displays (165 heads)	4,000
Packard Bell-NEC	PC assembly	500 (1999)
Inventec	Low-end PC assembly for Compaq	250
Fullarton	Low-end PC assembly for IBM	300 (assembly only)

Source company interview and newspaper articles

4 5 The Microcomputer Industry as New High Volume Production

The generic characteristics of NHVP were described in Chapter 2, based on a detailed comparison of four text-book NHVP models JIT/TQM (Sayer, 1986), Lean Production/ Lean Supply (Lamming, 1993, Womack, Jones, and Roos, 1990), Mass Customisation (Pine, 1993), Time-Based-Competition (Stalk and Hout, 1990) The purpose of this section is to determine the extent to which the microcomputer industry matches the textbook picture of NHVP, thereby providing the necessary basis for analysing the geographical configuration of the supply network in Chapter 5 The main characteristics of the value chain are discussed under the same headings as used in section 2 3 2 customer relations and distribution, product development, the final assembly plant, corporate organisation and supplier relations

Much of the information in this section is based on the answers, of nine responding focal companies, to the questions in the postal questionnaire that was specifically designed with the aim of establishing the relevance of NHVP concepts to the microcomputer hardware industry Most questions were posed using a Likert scale of one to seven, where one indicates a weak match with textbook NHVP while seven indicates a very strong match[4] The use of the scale, provided 'semi-statistics' which facilitate the qualitative analysis

Each sub-section starts with a table listing the relevant questions in the postal questionnaire and the average score for these questions The small number of questions that did not involve the Likert scale were not included in the tables below The original questionnaire was not numbered, but the questionnaire in Appendix B 3 and references in the text below have been numbered for the purpose of discussion For the same reason, the wording and the order of the questions in the text below have been slightly modified Finally, for space reasons, the results of a small number of questions are not discussed in the text The answers to questions 13 and 14 were ignored because they were misinterpreted by most respondents

Together the tables provide a broad overview of the relevance of the various elements of NHVP and deviations from the concepts are quickly identified The data are analysed and supplemented in the main text using information obtained during the face-to-face interviews The tables do not include figures for the number of respondents per question or measures of dispersion such as range or standard deviation Where range or deviation were important issues in the interpretation of the results this is indicated in the text

[4] The only exception being Q59 Here a score between the two extremes indicates a match with textbook NHVP

4 5 1 Customer Relations and Distribution

Table 4 8 Average score for questions regarding customer relations and distribution

Q1	Does the company offer a small or a wide variety of computer systems? (1 = a very limited variety 7 = an extensive variety)	*6*
Q2	To what extent are the products customised to individual customers? (1 = not at all 7 = 100 per cent)	*6*
Q3	How important is it to respond quickly to customer demand for changes with new or modified products? (1 = not at all important 7 = absolutely essential)	*6*
Q5	Prominence of goal in distribution strategy minimise the order to delivery cycle time (1 = receives no particular attention 7 = Very important part of our strategy)	*7*
Q6	Prominence of goal in distribution strategy minimise the distribution cycle time (1 = receives no particular attention 7 = Very important part of our strategy)	*7*
Q7	Prominence of goal in distribution strategy maximise delivery reliability/ consistency (1 = receives no particular attention 7 = Very important part of our strategy)	*7*
Q8	How would you describe the level of integration between assembler and the distribution channel? (1 = arm's length relationship 7 = strongly integrated value chain)	*5*
Q9	Intensity of information sharing with the downstream channel partners information on current demand for end-products (1 = no info Sharing 7 = Intensive info sharing)	*6*
Q10	Intensity of information sharing with the downstream channel partners information on demand forecasts (1 = no info Sharing 7 = Intensive info sharing)	*6*
Q11	Intensity of information sharing with the downstream channel partners information on future product development projects (1 = no info sharing 7 = Intensive info sharing)	*6*
Q12	How intensive are your efforts to build a long-term relationship with your customers? (1 = no efforts 7 = central to our strategy)	*7*
Q17	How would you describe the negotiations with the distribution channel? Cut throat, strong partnership, or somewhere in between? (1 = cut throat 7 = strong partnership)	*4*
Q62	Is competition in your industry based totally on product differentiation, totally on price competition, or somewhere in between? (1 = price competition 7 = product differentiation)	*4*

Source postal questionnaire, 1999

In line with the characteristics of NHVP approaches outlined in section 2 3 2 – notably JIT/TQM (Sayer, 1986), Lean Production/ Lean Supply (Lamming, 1993, Womack et al , 1990), Mass Customisation (Pine, 1993), Time-Based-Competition (Stalk and Hout, 1990) – all respondents to the postal questionnaire stressed that competition in the industry was based on both price and product differentiation (Q62) Companies generally offered a wide variety of computer systems (Q1), to a great extent customised for individual customers (Q2) The interviews showed that companies targeted a range of market segments, although some of the companies had a clear core capability Most companies served both the home and business segments The exceptions were Sun, AST-Samsung, Apricot-Mitsubishi and Digital[5] The latter three companies had been producing for the home segment until 1998 but were forced out of this market in the period 1997–98 Within the main segments, companies served various sub-segments such as first-time buyer, enthusiast, small and medium scale enterprise, mid-range corporate, corporate, government, professional, educational, financial, desktop publishing, etc And within these sub-segments the companies generally offered a high range of pre-set configurations or customised solutions

Textbook NHVP approaches are characterised by much attention to the reduction of time and inventories in the delivery system (Hise, 1995) In line with this, minimisation of delivery cycle time (Q5) and distribution cycle time (Q6) as well as the maximisation of delivery reliability (Q7) figured as very important goals in the distribution strategies of all focal companies The focal companies worked towards very short order-lead times – the time lapsed between the customer placing an order and proof of delivery to the customer (either end-customer or distribution partner) Typically, the target order lead time was less than five days (some companies would actually guarantee delivery within five days), although the lead time would depend on the type of system, the type of customer and the type of contract (see Table 4 9) Thus, the high end systems typically involved higher order lead times, which partly explains the relatively high order lead time of Digital Order lead times were less relevant for large corporate accounts Here, orders could be very large and often involved a roll-out schedule where an agreed number of units were delivered in a sequence of dates In many cases these corporate customers were more interested in predictability of delivery to the day The distribution systems of the focal companies were flexibly organised to be able to satisfy both types of demand

The minimisation of the lead times was strongly facilitated by the operation of an assembly plant in each of the triad markets, thereby reducing the physical distance to the customers As will be discussed in section 4 5 4, this spatial configuration was largely driven by the desire to reduce delivery and distribution cycle time

Lead times and inventories were also minimised by reducing the number of legs in the outbound logistics structure Thus, in nearly all cases the assembly facility operated as a sole European Distribution Centre (EDC) from where products were shipped directly to the customer Sun was the only company that operated its main EDC off site, in The

[5] Intel produced a wide range of systems for the OEM market

Netherlands Most companies did work with one to three remote merge centres in central European locations where they would store monitors and other peripherals However, in most cases these centres were not used to store the actual systems The centres merely served as facilities to merge the peripherals with the systems that were on their way to the customer "The logic is that once it is on the move, it is on the move, it doesn't stop" (Interview Hennesey, Dell, October 1999) Even the outbound logistics system of Sun, involving an EDC in The Netherlands, was organised in a broadly similar way Compaq was the only company that structurally kept inventories of some computer systems in an additional off-site centre (Amsterdam) [6] However, even Compaq shipped part of its products from Scotland directly to the customer

Table 4 9 Target order lead times at the focal companies

Focal Company	*Target order lead times*
Dell	Between 2–5 days
Gateway	<5 days
Apple	<5 days
Intel	No data
AST-Samsung	<4 days
IBM	<5 days for all
Compaq	<5 days most common, but depends on customer
Digital	<10 days for everything
Packard Bell-NEC	<4 days
Apricot-Mitsubishi	<3 days for low-end and <5 days for servers
Sun Microsystems	<5 days for low-end systems, <10 days for work-group servers and storage products, <25 days for high-end products

Source company interviews 1999

In effect the outbound logistics structures of the focal companies were leaner than the value added logistics models outlined in section 2 3 2 (e g Van Hoek, 1996) The outbound logistics chain no longer involved in-channel inventories positioned in value added logistics facilities in the various markets while the inventories in the warehouses at the focal companies' production plants were minimised as well, as a result of the build-to-order strategy applied by the focal companies (see section 4 5 3)

[6] Other companies notably Packard Bell-NEC and Sun stored finished computer systems at off-site warehouses on an incidental basis, e g only when computer systems were pre-built to satisfy a large contract

The geographical configuration of assembly plants and the outbound logistics systems went a long way to reduce lead time and minimise inventories However, channel partners downstream in the distribution channel, i e value-added resellers, dealers and retailers, involved additional inventories and added to the distribution cycle time According to one source, in 1999 dealer channels could hold as much as 40 days of inventory (Lyons, 1999a) In line with the textbook NHVP approaches, focal companies worked towards the minimisation of inventory levels and lead time at these levels as well

One important strategy towards this end has been the elimination of layers in the distribution chain, particularly in the form of a 'direct sales' strategy Direct sales refers to all types of sales where the vendor is transferring a product directly to an end user without releasing it to a third party [7] The customer can either order remotely (via fax, phone, mail, e-mail or internet site), after a walk-in (direct-retail) or after a scheduled face-to-face meeting The opposite is indirect sales, where during the sales process to the end-user a third party (i e a value-added reseller, a distributor, a dealer or a retailer) takes physical ownership of the product

During the 1990s, established computer makers lost market share to new arrivals such as Dell and Gateway, competing with a direct model, cutting out the added costs of middlemen in the distribution chain The order process involved less organisation and communication layers, allowing for a more streamlined order entry and an earlier visibility of orders Furthermore, the direct contact with the customers meant that these companies could forecast demand more accurately than competitors such as Compaq, who had had serious difficulties with this (*The Irish Times*, 23-04-99) All this allowed lower inventory levels and a reduction in time lost due to double handling

In the face of this new competition other computer makers were forced to adapt their distribution strategy and by 1999 nearly all focal companies were already selling part of their output directly to the end-customer and were planning to expand their direct sales

[7] There has been some confusion related to the word 'direct' in terminology within the distribution industry but in this dissertation the definition of Dataquest will be used (*Dataquest* web site, www Dataquest/ channel htm, accessed 11-03-99)

capabılıty (see Table 4 10) Nearly all focal companıes had a dırect face-to-face sales force targetıng the corporate and government market segments Furthermore, ın the perıod 1997–'99 Apple, Compaq, IBM and Packard Bell-NEC all ımplemented a phone/fax/ınternet dırect sales strategy, at least ın the mam European markets[8] (for Packard Bell-NEC see Black (1998), for Apple see Lyons (1998a), for Compaq see August (1998)) However, most of the new entrants to the dırect sales market, retaıned the ındırect channels sınce they stıll served a large sectıon of the mıcrocomputer market In 1999, Gateway, untıl then only sellıng dırect, created an ındırect channel by lınkıng up wıth value-added resellers to complement ıts face-to-face sales force

Table 4 10 European dıstrıbutıon channels of the focal companıes, 1999

	Direct sales				Indirect sales	
	phone/ fax	Internet	Retail	face-to-face	value-added reseller/ dealer/ distributor	retail
Dell	x	x		x		
Gateway	x	x	x	x	x	
Apple	x	x		x	x	x
Intel				OEM trade		
AST-Samsung				x	x	withdrew '97
IBM		planned		x	x	x
Compaq	planned	x		x	x	x
Digital				x	x	
Packard Bell-NEC	x	x		x	x	x
Apricot-Mitsubishi				x	x	withdrew '98
Sun Microsystems	x			x	x	

Source company ınterviews, 1999

As regards the ındırect channels, textbook NHVP approaches prescrıbe a strong ıntegratıon of manufacturıng facılıtıes wıth the dıstrıbutıon channel (Pıne, 1993, Stalk and Hout, 1990) In lıne wıth thıs the average score for the level of ıntegratıon between the focal companıes and theır dıstrıbutıon partners was five, ındıcatıng a faırly strong level of ıntegratıon (Q8) One strategy towards thıs end ınvolved the reductıon ın the number of resellers and retaılers wıth whom stronger relatıonshıps were forged For example, ın 1999, IBM was ın the process of reducıng ıts number of busıness partners ın Europe from 700 to 20 Sımılarly Compaq ıntended to focus on 10 to 20 partners ın

[8] AST-Samsung had been plannıng to create a dırect phone/fax/ınternet sales channel as well (Casey 1997a) However these plans were taken over by events when AST-Samsung wıthdrew from the home computer market

Europe Apricot-Mitsubishi worked with six to eight resellers in Europe All respondents indicated an intensive sharing of information with their downstream channel partners on current demand for end-products (Q9), demand forecasts (Q10), and on future product development projects (Q11) Compaq was in the process of establishing a shared inventory system with its major distribution partners

4 5 2 Product Development

Table 4 11 Average score for questions regarding product development

Q18	How important are product innovations (e g new features, new technologies, new products) to the success of your business (1 = not at all important 7 = crucial)	*6*
Q19	How important is it to respond quickly to customer demand for changes with new or modified products? (1 = not important for the success of our business 7 = crucial for success)	*6*
Q20	Importance of goal in the company's R&D strategy minimise new product development/ introduction time 1 = receives no particular attention 7 = very important part of our strategy	*5*
Q21	Importance of goal in the company's R&D strategy maximise rate new product introduction 1 = receives no particular attention 7 = very important part of our strategy	*6*
Q22	How important are incremental innovations versus breakthrough innovations (e g new products, new technologies) to the success of your company? 1 = breakthrough 7 = incremental	*2*
Q23	In the product design process, what attention is paid to the manufacturability of design? 1 = limited attention 7 = central to design process	*5*
Q24	To what extent are product and process development activities integrated? 1 = carried out sequentially and in separate teams 7 = simultaneously in one team 4 = in between	*4*
Q25	To what extent does the company use flexible technologies (e g CAD) in the development process?	*6*

Source postal questionnaire, 1999

As will be discussed in section 4 5 5, microcomputers have developed many characteristics of, what Langlois and Robertson (1995) call, modular systems where many of the components are developed and produced by specialised suppliers As a result, in most focal companies new product development mainly involved the integration of industry-standard components, developed by suppliers The emphasis of R&D lay firmly on the 'D'-side However, all of the focal companies retained some in-house design capability, particularly in relation to motherboard, enclosure, and software design Furthermore, even the integration of out-sourced components could potentially involve a substantial amount of development resources and time New components could require new motherboard and software design and all components needed to be tested and certified Hence, many of the product development issues associated with NHVP, raised in section 2 3 2, proved relevant

Textbook NHVP concepts all stress the importance of product innovations and quick response to changing customer desires (Pine, 1993, Stalk and Hout, 1990, Womack et al , 1990) In line with this, these issues were perceived to be almost crucial to the success of all focal companies (Q18 and Q19) Likewise, product development/introduction time and the rate of new product introduction were important aspects of the strategies of nearly all focal companies (Q20 and Q21) Most interviewees mentioned a median age of product offerings of three or six months (Q4) The only focal companies with a higher figure were Apricot (nine months) and Sun (15 months) At odds with the textbook NHVP concepts, breakthrough innovations were generally perceived more important for the success of the company than incremental improvements (Q22) In line with the NHVP concepts there was a strong emphasis on process and business innovations in the microcomputer industry In fact, profitability in microcomputer manufacturing had become "a function of skills in low-cost, flexible high-volume assembly, rather than innovative capability in technology development" (Angel and Engstrom, 1995, p 81) and the competitive position of recent star companies such as Dell was largely a result of the successful implementation of process and business innovations

NHVP approaches prescribe that development resources from various functional areas are brought together in a team, preferably under one roof, in close proximity to the production plants (Pine, 1993, Womack et al , 1990) In line with this, there was evidence of a strong integration of the development, production and sales/marketing functions in all focal companies System development was typically organised in teams that involved sales/marketing, supply management and production staff The main corporate product development functions were in most cases located near the main production facilities (see Table 4 12) The exceptions were AST-Samsung and Apricot-Mitsubishi AST-Samsung carried out system development in California while its main production site was located in Texas Apricot-Mitsubishi manufactured its computers in Scotland and product development functions were based at HQ in Birmingham The main PC development functions of IBM were based near the main production plants in Raleigh but the company incorporated technology from multiple sites including some outside the USA However, the plan was to centralise PC technology development activities in Raleigh (Angel and Engstrom, 1995) Not all team members were resident at the development facilities for the entire duration of product development Production and sales/marketing staff remained principally part of their respective organisations and would meet the development team for short periods or pre-arranged meetings

In spite of this, the idea of simultaneous product and process development (Womack et al , 1990) was not fully born out (Q24) The average score for the level of integration of product and process development activities was four, indicating that, at least in a number of the focal companies, the two activities were partly organised independently of one another However, the production functions did have a substantial input in product development, which substantially reduced the time to introduce new products Furthermore, the development teams typically did pay substantial attention to the manufacturability of design (Q23) – an important element of textbook NHVP approaches (Handfield, 1993)

> We have people down from here [the production plant] based in R&D, for things like design for manufacturing and design for test So they would be making sure that our improvements are put into design [ ] We have objectives And a good example of that is that several years ago it took us about sixty minutes to assemble a PC and at the end it was five minutes So we managed to get the build time right down (Interview Campbell, Apricot-Mitsubishi, July 1999)

Table 4 12 Location of main development groups of focal companies, 1998-'99

	HQ (typically including sales and marketing)	Main development locations[a]	Main production plants
Dell	Roundrock, Austin	Roundrock, Austin	Roundrock, Austin (several sites)
Gateway	North Sioux City (SD) for home systems Irvine (CA) for business systems (legacy of ALR acquisition) San Diego (CA) for corporate HQ	North Sioux City (SD) for home systems Irvine (CA) for business systems (legacy of ALR acquisition)	North Sioux City (SD) for home systems Irvine (CA) for business systems (legacy of ALR acquisition)
Apple	Cupertino (CA)	Cupertino (CA)	Sacramento (CA)
Intel	Santa Clara (CA)	Portland (OR)	Portland (OR) for early life production Du Pont (WA) for volume production
AST-Samsung	Irvine (CA)	Irvine (CA)	Fort Worth (TX)
IBM	Raleigh (NC)	Raleigh (NC) and Boca Raton (FL) for system development smaller server development function in Greenock, Scotland Component development in New York, Texas and Vermont, as well as outside the USA, including in Ireland and Scotland	Raleigh (NC)
Compaq	Houston	Houston Fremont (CA) for high end sever development (legacy of Tandem acquisition)	Houston Fremont (CA) for high end sever production (legacy of Tandem acquisition)
Digital	Maynard (MA)	Maynard (MA) Marlborough (MA)	Salem (MA)
Packard Bell-NEC	Sacramento (CA)	Sacramento (CA) Los Angeles (company planned to centralise development in Sacramento)	Sacramento (CA)
Apricot-Mitsubishi	Birmingham	Birmingham	Glenrothes, Scotland
Sun Microsystems	Palo Alto (CA)	Menlo park (CA) (10 miles from Palo Alto) Dublin for software development	Palo Alto and Beverton (CA)

Source company interviews, 1999, For component development sites IBM Angel and Engstrom (1995)
Note [a]Does not include world-wide localisation centres

4 5 3 The Assembly Plant

Table 4 13 Average score for questions regarding the assembly operations

Q26	Character of assembly process (1 = fully standardised mass production 7 = one-of-a-kind production where each final product is different from the next)	*6*
Q28	Prominence of goal in production strategy No or small buffer inventories (1 = receives no particular attention 7 = very important part of our strategy)	*7*
Q29	Prominence of goal in production strategy Increase inventory turnover (1 = receives no particular attention 7 = very important part of our strategy)	*7*
Q30	Prominence of goal in production strategy Minimise the lot size (1 = receives no particular attention 7 = very important part of our strategy)	*5*
Q31	Prominence of goal in production strategy Minimise set-up times (1 = receives no particular attention 7 = very important part of our strategy)	*6*
Q32	Prominence of goal in production strategy Bring down production cycle time (per major phase of main sequence) (1 = receives no particular attention 7 = very important part of our strategy)	*7*
Q33	Prominence of goal in production strategy Maximise value added as percentage of total elapsed time (1 = receives no particular attention 7 = very important part of our strategy)	*6*
Q34	Adoption of management philosophies in production strategy Total process efficiency (1 = to no extent 7 = to a great extent)	*6*
Q35	Adoption of management philosophies in production strategy Elimination of waste (1 = to no extent 7 = to a great extent)	*6*
Q36	Adoption of management philosophies in production strategy TQM (1 = to no extent 7 = to a great extent)	*7*
Q37	Adoption of management philosophies in production strategy Continuous process improvement (1 = to no extent 7 = to a great extent)	*7*
Q38	Adoption of management philosophies in production strategy Flexible production (*the ability to change quickly between products*) (1 = to no extent 7 = to a great extent)	*6*
Q39	Adoption of management philosophies in production strategy Integration of thinking and doing (*worker involvement in defining and improving the process*) (1 = to no extent 7 = to a great ext)	*6*
Q40	To what extent is flexible machinery used in the assembly process? (1 = not used 7 = used to a great extent)	*3*
Q41	To what extent do you employ computer-aided production management techniques in system assembly? (1 = not at all 7 = used to a great extent)	*6*

Source postal questionnaire, 1999

The postal questionnaire and interviews provided ample evidence for the NHVP-related flexible processes, work practices and technologies and product engineering strategies outlined in section 2 3 2 – addressing the challenge of combining product variety with production efficiency

General NHVP-related management philosophies such as total process efficiency, elimination of waste, total quality management, continuous process improvement involving everybody (*kaizen*), integration of thinking and doing and flexible production were to a great extent adopted in the production strategies of all focal companies (Q34-Q39) Likewise, related goals such as maximisation of value-added as a percentage of total elapsed time, reduction of buffer inventories, increase in inventory turnover, minimisation of lot size, minimisation of set-up times and reduction of the production cycle time figured prominently in the production strategies of all focal companies (Q28-Q33)

In fact, as prescribed by the NHVP approaches (Handfield, 1993, Pine, 1993, Stalk and Hout, 1990), the central principle of the JIT production philosophy, i e , only doing work when needed, in the necessary quantity at the necessary time, was often followed right to the front end of the production process Thus, most focal factories, except the Compaq and Apple plants, had implemented a build-to-order (BTO) strategy, combined with short order lead times, for all of their products Most companies did generally not build no systems to stock Instead, computer assembly activities were usually backed up by actual customer order receipt The strategy resulted in very low finished good inventory levels The two main exceptions to the BTO strategy were Compaq and Apple These two companies were still building part of their products to replenish specific stock levels, although both companies were making inroads into the BTO model with some of their products For example, Compaq built 30 per cent of its output to order and 70 per cent to stock, working towards a five-day inventory rule

The other companies would only build to stock in exceptional situations Thus, some companies would revert to building computers to stock in periods of extremely slack demand, so staff levels could be retained Equally, some companies would pre-build systems in anticipation of a forecasted large hike in demand (e g during Christmas) Apart from this, some companies occasionally chose to pre-build computers for large contracts, which would lead to certain stocks of finished goods However, although these systems were built ahead of delivery date, they were backed up by actual customer orders

The actual production processes were typically very flexible and efficient The production process typically involved an uninterrupted sequence of system assembly, software downloading, testing and packing This could be organised in a traditional line process, a cell process, or a hybrid process (part line, part cell), while some plants operated a mix of processes Only a small number of focal plants were still involved in (limited) component production activities, notably the assembly of a small number of printed circuit board models

Flexibility and efficiency were not really the outcome of the widespread use of flexible machinery The average score in response to the question regarding the use of flexible machinery (Q40) was three – indicating a limited use In fact, the average score was increased by the high score of two companies still involved in printed circuit board (PSB) assembly (IBM and Compaq) The actual computer assembly process was largely a manual process, involving only hand-held power tools to screw the components Only the downloading of software and testing was carried out by flexibly programmed computers

Flexibility and efficiency was partly the result of a strong integration of the manufacturing process Production was strongly integrated by the use of computer-aided production management techniques, which the focal companies used to a great extent (Q41) In many cases the computer systems were automatically conveyed to the various stages of the manufacturing process The manufacturing processes were also strongly integrated with the various upstream and downstream functions The level of integration can be illustrated by the situation at Compaq and Gateway

> Compaq's Vertical Integrated Manufacturing [is] a streamlined high-volume manufacturing process that dramatically increases production The U-shaped lines consolidate the entire manufacturing process onto one integrated line, allowing real time customisation, testing and quality checks The end result is lower cost product produced in a shorter period of time (*Compaq* web site, www Compaq com/newsroom/pr/1999, accessed 12-12-00)

> Our [Gateway's] system does not allow for high volume automation tools There are no robotics involved The software installation process, is hardwired into Gateway's IBM AS400 platform allowing the pre-installation, test and verification processes to be entirely computerised The fully integrated JBA system handles everything from order entry and finance approval, through each stage of manufacturing to dispatch The BOM is checked in

> test and verification electronically, effectively an automated inventory check, and a signal is sent to end of line to assemble the accessory boxes (Gallagher, 1999)

However, at the few plants that were still involved in PCB assembly, the PCB assembly process was not integrated with the actual computer assembly process The companies involved treated the PCB assembly activities as a separate operation PCB assembly operations produced not only for the on-site system assembly operations but also for other system assembly plants of the same company and, in one case, plants of other companies

Flexibility and efficiency were strongly facilitated by component modularization and product simplification – in line with textbook NHVP (Pine, 1993) In fact, as will be discussed in section 4 5 5, the microcomputer had developed many characteristics of a modular system where the interfaces among components were standardised and publicly known (Baldwin and Clark, 1997, Langlois and Robertson, 1995) Because of this, specialised component suppliers could sell their industry standard components to a large number of microcomputer assemblers, as long as their technology maintained its ability to connect to the standard bus For their part, computer assemblers were able to share and swap industry standard components from various sources, enabling them to offer a high variety of configurations

The modularization strategy was applied to the proprietary technologies as well Most of the focal companies in this research competed by differentiating their products from their competitors, particularly on the basis of reliability/functionality and aesthetic design As regards reliability/functionality, most focal companies designed their own motherboards Companies typically restricted themselves to a limited number of industry standard form factors such as NLX and ATX, particularly for the lower-end systems[9] However, for every form factor, companies could have several variants each with its own functionality and level of upgradability As regards aesthetics, for the case design companies would again restrict themselves to the industry standard form factors However, the focal companies could offer a variety of company specific enclosure styles, such as desktop, tower, mid-tower, mini-tower, micro-tower, etc. On top of that, companies could have a variety of interchange front bezels. The different motherboards would fit multiple enclosures, leading to a high product variety.

Companies had started to question the value of a high variety of external designs and nearly all focal companies had recently reduced the number of enclosures on offer or were planning to do so. Thus, in 1999 Dell and Packard-Bell and Mitsubishi worked with only four enclosure models (excluding portable computer enclosures) and Gateway was planning a similar number. However, the actual number of enclosure models partly depended on the business segments the companies were active in. Thus, companies competing in the high-end server market, such as IBM, DEC, Compaq and Sun, tended to work with a higher number of enclosure models. However, in these companies as well, there was a strong drive to bring the number of enclosures down. "That [reducing the number of enclosures] is something we are working furiously hard at. Our product offering has reached widespread proportions and is now becoming uncompetitive" (Interview Aitken, Sun, 1999).

Component modularization and the largely manual character of the computer assembly process meant that set-up times were very short. In fact, the changeover from one computer configuration to another, or from one order to the next, required no new set-up and, consequently, no time was wasted. Operators simply read the system-specific assembly docket that travelled with the system and assembled the required component(s) that either travelled with an individual computer or were constantly available to the operator. Similarly the software downloading process required no order specific set-up. Factory-installed servers automatically identified the individual systems, downloaded the order specific software and carried out the required tests.

[9] The form factors of the motherboard describes its general shape, what sorts of cases and power supplies it can use, and its physical organisation.

Thus, the production process was broadly similar for a wide range of products and orders The main difference concerned the production cycle time In line with the textbook NHVP concepts, production cycle times of most models had been reduced to very low levels The actual assembly of desktop models typically took less than 10 minutes and the complete process including software downloading, testing and packaging took less than one hour However, very high-end severs, produced by only a few of the focal companies, could take up to eight hours to assemble and a further two days to test Therefore, these high-end systems were typically assembled in different cells/lines

The assembly process approached a 'one-of-a-kind' production process (as opposed to a fully standardised mass production process) (Q26) The textbook NHVP idea of batch-sizes of one (Pine, 1993, Sayer, 1986, Stalk and Hout, 1990) had basically become a reality in the focal plants Interviewees were generally unable to estimate the average batch size (Q27) The batch size would vary a lot, depending on the order loaded One day a plant could put through a small number of large batches while the next day it could be producing a multitude of very small batches Furthermore, some plants reserved separate lines for the continuous production of high running configuration However, all interviewees indicated that the manufacturing systems were capable of dealing with batch sizes of one, and in the majority of cases the entire production system was designed toward this end

Clearly the manufacturing processes of the focal companies contained many elements of a textbook JIT manufacturing process However, there was one important difference, which was largely a consequence of the market conditions faced by the microcomputer companies The market for microcomputers was characterised by strongly fluctuating and unpredictable demand In such an environment a BTO strategy in combination with very short lead times resulted in strongly fluctuating and unpredictable demand from final assembly on upstream functions As discussed in Chapter 2, a textbook JIT manufacturing system can not deal with highly irregular and unpredictable pulls from final assembly since it would lead to inefficient use of labour and machinery upstream (Sayer, 1986)

In the factories of the focal companies this problem was partly solved by a reduction of the number of separate phases in the production process Production typically involved a very short uninterrupted sequence of activities with no in-process buffers In a sense, within the boundaries of the plant there were almost no up-stream activities The first upstream activity to be encountered was component production and that virtually all took place outside the boundaries of the plant, at the component suppliers

However, the fluctuating demands on manufacturing still had the potential to cause regular periods of zero productivity of workers In order to maintain flexibility and efficiency all focal companies relied strongly on the use of flexible labour, particularly numerically All companies made extensive use of temporary labour, overtime and other flexible roster arrangements Temporary workers typically accounted for 20 to 30 per cent of the work force at peak periods (see Table 4 14) In the actual manufacturing operations the share of temporary workers could be substantially higher – 50 per cent in the case of Packard Bell-NEC Two of the focal companies, Dell and Gateway, made relatively limited use of temporary labour According to a communique of Dell, the reason for this was that a permanent work-force is more productive than having large numbers of temporary workers (Mulqueen, 1999a) However, part of the explanation might have been the tight Irish labour market At the time, the two companies were constantly short of labour (Mulqueen, 1999b) and fixed contracts might have been the only way to attract the required number of workers Up until 1999 Dell had always used large amounts of temporary workers (accounting for up to 50 per cent of its labour force) and, at the end of 1999, Dell was again heavily advertising temporary positions for the peak Christmas season (Beesley, 1999, Mulqueen, 1999b)

Numerical labour flexibility was by far the most important strategy for addressing the problem of fluctuating demands Table 4 15 shows that on a scale from one (not important) to seven (very important) numerical flexibility scored seven Other NHVP-related strategies for addressing the problem of fluctuating demands, such as the short-term adjustment of marketing (Womack et al , 1990) and multi-locational capacity management (Lammıng, 1993) were far less ımportant Furthermore, where used, marketıng was really more applıed as a strategy to overcome problems wıth component supply rather than as a strategy for relıevıng the pressure on the ın-house productıon operatıons In lıne wıth textbook NHVP approaches, the employment of subcontractors, and productıon-to-stock were seldom used as strategıes for addressıng the problem of fluctuatıng demands

Table 4 14 Temporary workers as a percentage of total workforce at peak perıod

Focal Company	*Percentage temporary workers at peak perıod*
Dell	2 5
Gateway	5
Apple	30
Intel	No data
AST-Samsung	29
IBM	40
Compaq	30
Dıgıtal	33
Packard Bell-NEC	25
Aprıcot-Mıtsubıshı	20
Sun Mıcrosystems	18

Source company ınterviews 1999

Table 4 15 Importance of varıous strategıes for addressıng the problem of fluctuatıng demands

Strategy	*Average score (1 = not ımportant 7 = very ımportant)*
Numerıcal flexıbılıty	7
Subcontractıng	3
Multı-locatıonal capacıty management	4
Adjust marketıng	3
Manufacture to stock	2

Source company ınterviews 1999

4 5 4 Corporate Organısatıon and Subsıdıary Roles

Table 4 16 Average score for questıons regardıng corporate organısatıon and subsıdıary roles

Q57	To what extent does the company dıfferentıate ıts products for specıfic geographıcal markets (e g North Amerıca - Europe - Asıa)? (1 = to no extent (global products) 7 = to a great extent)	*3*
Q58	To what extent ıs thıs facılıty ınvolved ın the development of geographıcal market specıfic products? (1 = no ınvolvement 7 = systems sold by thıs subsıdıary are developed locally)	*3*
Q59	Character of the organısatıonal structure of your company (1 = strongly hıerarchıcal 7 = strongly networked (flat organısatıonal structure)	*5*

Source postal questıonnaıre, 1999

As outlıned ın sectıon 2 3 2 the NHVP system of multıregıonal productıon ınvolves the creatıon of a 'top-to-bottom' – paper concept to finıshed product – ıntegrated productıon system, ıncorporatıng R&D, productıon and marketıng capabılıty, ın all the major world markets (Womack et al , 1990) The ıdeal-type post-natıonal company wıll develop a set of products unıque to each major regıon These products wıll be produced wıthın the ındıvıdual regıons to serve the volume segments ın each regıon and they wıll be exported to other regıons to fill market nıches Fınally, the corporate organısatıon ıs characterısed by a combınatıon of decentralısatıon and centralısatıon to avaıl of economıes of scale and savıngs through standardısatıon ın development/productıon as well as savıngs through consolıdated purchases The corporate organısatıon of the focal companıes had many of these characterıstıcs, although ımportant elements were not fully born out

Thus, as dıscussed ın sectıon 4 3, nearly all companıes had at least one assembly and test facılıty ın each of the trıad regıons (Ohmae, 1985) North-Amerıca, Europe and East/South-East Asıa (see Fıgure 4 1) Exceptıons were Sun and Aprıcot-Mıtsubıshı There had been some recent ınvestment ın the emergıng South-Amerıcan market and two companıes had establıshed software configuratıon facılıtıes ın Australıa Apart from manufacturıng, the regıonal operatıons typıcally ıncluded substantıal sales and marketıng, servıce and regıonal headquarter functıons, although not always located ın the same locatıon (see Table 4 17 as well as Tables 4 5 and 4 7)

Figure 4.1. Location of microcomputer assembly plants of focal companies world-wide - 1998

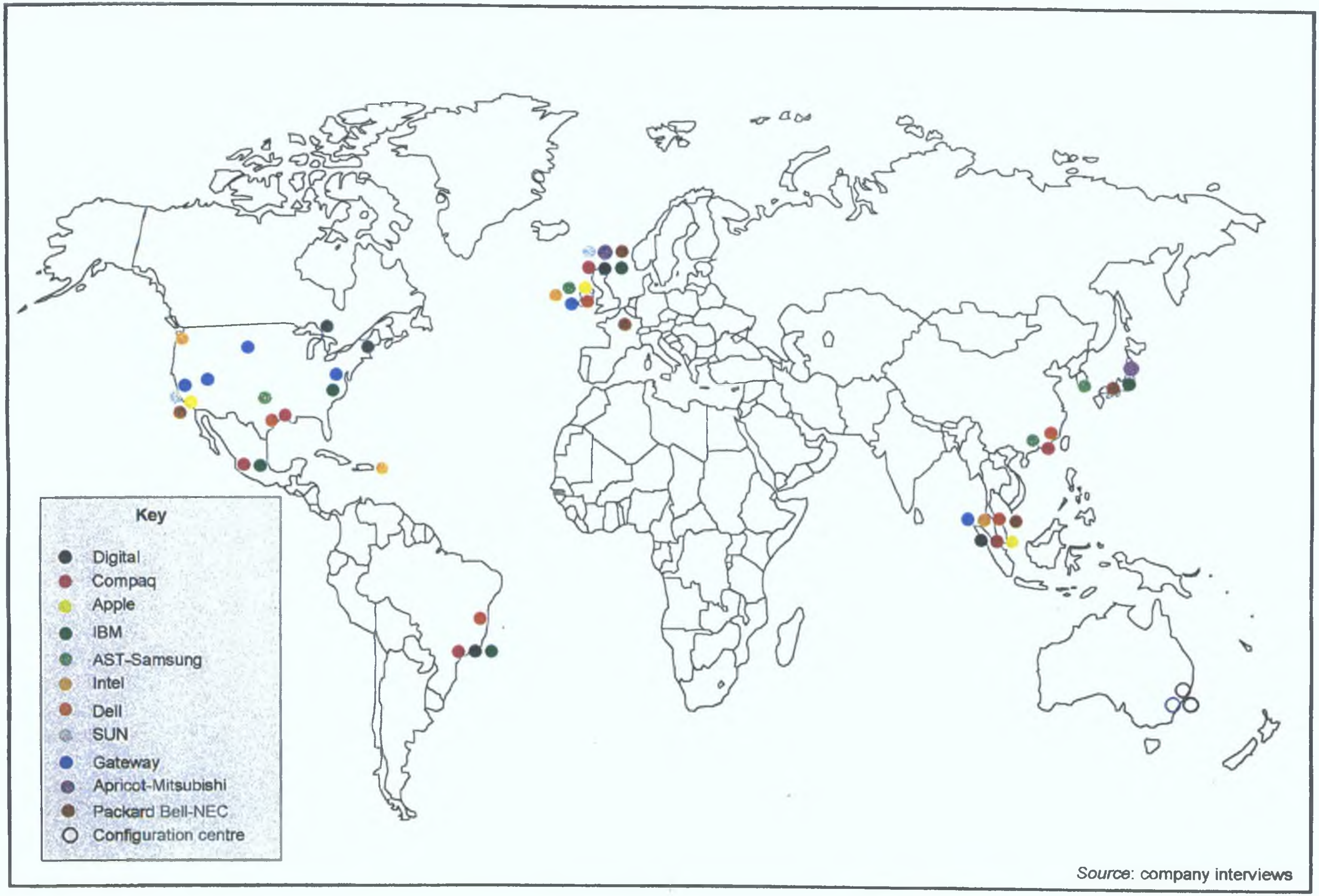


Table 4 17 Location of European operations of focal companies, 1998

	Location of system assembly plants	HQ European operations (seat of most senior executive European operations)	HQ Sales and Marketing
Dell	Limerick, Ireland	Bracknell, England	Bracknell, England and Bray Ireland (for home and small business division)
Gateway	Dublin, Ireland	Split between Dublin, Ireland and Uxbridge, England	Uxbridge, England
Apple	Cork, Ireland	Cork, Ireland	Paris
Intel	Leixlip, Ireland	No data	No data
AST-Samsung	Limerick, Ireland	London	London
IBM	Greenock, Scotland	Paris	Paris
Compaq	Erskine, Scotland	Munich	Munich
Digital	Ayr Scotland	Geneva	Geneva
Packard Bell-NEC	Livingston, Scotland	Wijchen, The Netherlands	Paris
Apricot-Mitsubishi	Glenrothes, Scotland	Birmingham, England	Birmingham, England
Sun Microsystems	Linlithgow, Scotland	Linlithgow, Scotland	London

Source company interviews, 1999

One of the main deviations from the system of multiregional production and the post-national company was the lack of substantial local-for-local R&D groups in the European operations, a reflection of the fact that companies were offering basically global products (Q57 and Q58) Rather than developing products unique to each major region and exporting these to other regions to satisfy niche markets, the level of differentiation for specific geographical markets was low in all companies Typically, the actual computer – the box in its various possible configurations – was the same for all markets, apart from, in some cases, country specific communication hardware The differentiation or localisation came with the loading of the software (language), the keyboard (language), the documentation (language) and country specific cables

The regionally specific product development requirements were therefore relatively small and most focal companies had concentrated their microcomputer development facilities in the home country Apart from UK based Apricot-Mitsubishi, which had its world-wide headquarters and development facilities in Birmingham, England, only two other focal companies had a genuine microcomputer development operation in Europe IBM had a significant development organisation at its mam manufacturing site in Scotland, responsible for the development of the 5000 server model, server boards, as well as several visual products However, the products were developed for IBM's entire global personal systems group, rather than for the European market per se, and the R&D function was part of IBM's R&D division headquartered in the USA, rather than part of an integrated European operation Likewise, Digital had a small design group of 10 engineers in Scotland involved in the design of single-board embedded servers for niche world markets

Apart from this, most companies, notably Dell, IBM, Compaq, Digital and Packard Bell-NEC, had a separate group in the European operations, carrying names such as *Customer Special Systems* or *Special Bids* These groups, involving a mixture of development engineers and sales and marketing staff, were involved in the configuration of special systems for large corporate accounts If a customer required something different from the standard product configurations, i e extra hardware or the downloading of their own software requirements, one of the responsibilities of these groups would be to liase with the customer and make sure that the systems were properly configured and ready for installation However, the activities generally did not involve genuine product development Typically, the engineers would take a corporate standard product and work with qualified components to take it to another level of configuration for specific customers

Apricot-Mitsubishi aside, Dell was the only focal company in this research that was in the process of creating a separate group with local-for-local component expertise This *European Products Group* grew out of the software localisation group (see below) The group included a small team of engineers, mentored by the design group in the USA, with expertise in Europe-specific communication hardware as well as regulatory and environmental compliance As regards communication hardware the group identified European suppliers, brought products through a business justification process and carried out the necessary qualifications

Regarding software development, nearly all focal companies had, what was generally referred to as, a localisation group, located at the European manufacturing facilities The precise remit of the localisation group varied from company to company One of the responsibilities of these groups involved the organisation of the development or supply of language-specific components that differentiated the product for the various geographical markets, i e mainly firmware, keyboard, power cable and printed/electronic documentation However, the actual software development content of their activities was limited Typically, this mainly involved the management of local subcontractors that carried out the localisation on behalf of the focal companies Electronic documentation was typically developed in the English language The localisation group received this US golden master, sent it to local translation houses, and subsequently outsourced the reproduction of CDs/printed media and in some cases the kitting of the accessory boxes, to local subcontractors Actual product-software development was limited to the translation of firmware and its integration into the operating system

Another, larger, responsibility of the localisation group involved process development the development of software for the European manufacturing operations The high-volume production and test of language specific computers and the production of special offerings for corporate accounts, in some cases incorporating a certain amount of geography-specific components, requires the creation of a large amount of process software One of the main activities of the localisation group involved the continuous creation of scripts to support the downloading of operating systems, firmware, applications and new hardware drivers (mostly for the non English language) as well as the testing of systems in a NHVP environment

Apple and Digital were the only two companies that carried out a (limited) amount of fundamental operating system and application software development and testing in Europe Apple housed an operating system development group at its manufacturing facility in Cork, while Digital used a facility in Galway, Ireland However, organisationally, the development teams involved were part of, and reported back to, the design group in the USA These development teams were not part of an integrated

European production system as envisaged by Womack et al (1990) – their location was purely driven by the desire to use the local pool of skilled labour near an existing premises[10]

Finally, the limited amount of local-for-local R&D does not mean that the European operations played no role in the corporate product and process development process Apart from the above mentioned engineers involved in corporate development activities, the regional manufacturing, development and marketing operations included a substantial number of employees with technical skills and the organisation of the corporate development process typically involved a substantial amount of communication between these employees and the corporate design groups, partly to facilitate an input from the regions Component managers and development engineers as well as marketing staff with technical skills evaluated and discussed parts and system design with the development groups in the USA during formal design and project reviews Similarly, local programme managers and production engineers, particularly the members of new product introduction teams, were in regular discussion with the prime development sites, mainly to facilitate a smooth introduction of a new product to the European operations but also to discuss issues like manufacturability of design and process design in general

In line with the textbook NHVP concepts, the organisation structure of the focal companies was characterised by a combination of centralisation and decentralisation Interviewees were asked to rate the level of autonomy in relation to various elements of the European operations The results are presented in Table 4 18

Table 4 18 Autonomy levels European operations

	Average score (1 = no involvement 7 = full autonomy)
Product portfolio/ product strategy	3
Production process/ manufacturing system	5
Sales and marketing	6
Product pricing	5
Further investments	4
Purchasing / supplier selection	3

Source company interviews 1999

[10] Digital's operating system development team was located in its Galway facility that became available after closure of the micro-computer manufacturing facility at the end of the 1980s

Not surprisingly, given the earlier comments regarding product differentiation for different geographical markets, decision making regarding product portfolio/ product strategy and purchasing/ supplier selection were most centralised, although European operations were involved The product portfolio, i e the basic product road map, was devised in the USA with some input from the regions Thus, marketing groups and development/production engineers from the European and Asian operation were involved in regular communication with the product strategy groups in the USA to advise on developments in and requirements for the regions Furthermore, although the basic product road map was devised in the USA, the European operations typically had some discretion as to which parts of the corporate product range they were going to offer and manufacture in Europe

Partly related to this, purchasing and supplier selection was strongly centralised as well, although again, with some involvement from the regions A large part of supplier selection was driven by product development decisions that determined the component technology and, in many cases the supplier As described above, product development was typically strongly centralised in the USA, although the regional marketing groups and development/production engineers were consulted and could influence the technology road-map to a limited extent

However, even in those cases where product development did not immediately determine the actual component supplier, the actual supplier selection process was strongly centralised In order to reduce the number of suppliers and gain purchasing leverage, companies were increasingly looking for global suppliers For this purpose, all companies had created global procurement groups or commodity councils, responsible for the selection of suppliers and creating world-wide partnership deals for strategic or core components Apricot-Mitsubishi aside, to facilitate communication, these corporate purchasing groups were based near the prime development sites in the USA The European operations did have some involvement and influence Regional procurement or commodity groups were in regular communication with the global procurement groups or, in the case of Compaq, Digital and IBM, had representation on the various global commodity councils This allowed regional representatives to discuss the performance of current suppliers and to some extent, influence the selection of new ones European representatives could even propose new suppliers to be included in the approved-vendor-list, although this did not generally involve strategic components

The European operations typically had full autonomy regarding the selection of suppliers for non-strategic parts such as packaging, documentation, power cords and, in some cases, enclosures However, even these suppliers had to go through a standard approval process to be incorporated in the approved-vendor-list

European operations had a slightly higher involvement in decisions regarding further investment, but investment remained a corporate function Typically, European management was expected to identify opportunities, justify investments through a business plan and make proposals to the executive committee However, the plans had to be centrally ratified Furthermore, to an extent, capacity investments were driven by the corporate sales target

Companies generally had a higher level of autonomy regarding decisions on the production process The regional operations were strongly autonomous in decisions regarding plant lay-out, process flow and the extent of sub-contracting Plants were free to test different systems However, decisions were often based on a consensus reached with the global engineering group and large investment decisions had to be approved centrally Typically, the actual manufacturing system software, e g SAP, was the same across the regions Similarly, decisions on test times were taken centrally by the engineering groups in he USA

Autonomy was highest in the areas of sales and marketing and product pricing Marketing campaigns and, to some extent, the choice of distribution partners were the responsibility of the European sales and marketing groups Furthermore, the regions generally had a high degree of freedom in product pricing although, in some companies it had become tied in to global pricing

Finally, partly related to the lack of substantial local-for-local development groups, the high level of integration of the different elements of the regional production systems was not fully born out, or at least differed in character from that envisaged by Womack et al (1990) Although all companies had a regional production function, a sales/marketing function and, to a limited extent, a development function, the main lines of communication between the various functions ran primarily via the corporate headquarters in the USA

Thus, the regional sales and marketing functions typically discussed information on sales forecasts, market acceptance and product definition requirements directly with the corporate development and planning groups in the USA, rather than with the regional production and development functions Direct communication with the regional manufacturing and development operation was typically restricted to the execution of new product launches The limited level of integration obviously lessened the need for co-location of the manufacturing and sales/marketing functions of the European operations and probably partly explains the geographical configuration identified in Table 4 17 The strongest integration was found in the earlier mentioned *Special Bids* groups, involved in the configuration of special systems for large corporate accounts Manufacturing and 'development' staff were in regular contact with the sales and marketing staff, and even the end-customer, to discuss company specific requirements However, discussions mainly concerned issues regarding fulfilment and service, rather than actual product development As regards the integration between the regional manufacturing and development functions, the localisation groups were strongly integrated with the production function However, the main activities of these groups involved production process support, rather than product development The regional operating system development groups of Digital and Apple, and Dell's *European Product Group*, were feeding directly into the corporate development groups, rather than being part of an integrated regional production system

The degree and character of integration was partly reflected in the reasons for having a regional assembly operation in each of the three global markets The NHVP textbooks propose several reasons for establishing a 'top-to-bottom' presence in each triad market (see section 2 3 2) The focal companies were asked to rate the importance of these factors in driving the investment in an actual assembly operation (see Table 4 19) The outbound logistics related factors, i e 'holding down the delivery time/ distribution cycle time' and 'holding down transport costs', proved most important According to a Dell functionary, high shipping costs basically ruled out the importation of computer systems from South-East Asia to Europe (Mulqueen, 2000) Trade barriers had been important for a number of longer established companies at the time of the initial investment decision but had virtually disappeared and no longer played a significant role Similarly, exchange rate issues played a very modest role

Table 4 19 Reasons for having an assembly operation in Europe

	Average score (1= not important 7 = very important)
Hold down the delivery time/ distribution cycle time	6
Hold down transport costs	5
Overcome (potential) trade barriers	4
Exchange rate issues	2
'Being in touch' with the needs of the European market	5

Source company interviews 1999

The category 'being-in-touch with the needs of the European market aimed to address the idea that the regional assembly facilities needed to be in Europe to communicate the regional product design needs with the regional design and marketing groups (Womack et al , 1990) The average score of five suggests that the factor played a reasonably important role However, the associated discussions revealed that the question was misinterpreted and failed to measure the factor under consideration The score did not really pertain to the communication of product development issues It was considered important to be in touch with the needs of the European market However, "having an assembly operation in a certain country doesn't bring you that" (Interview Clarke, Dell, Oct 1999) "It is important to understand the different cabling and power requirements, but it is not essential to have a factory here [for the reason of being in touch with the needs of the European market]" (Interview Aitken, Sun, Aug 1999) The score of five partly expressed the role of the assembly facility in 'developing' and producing *Special Bids* for corporate customers Engineers of the Special Bids group visited corporate customers and the assembly facilities were sometimes used to host customers Therefore, having an assembly facility located in the same time zone as the customers was a plus However, the score of five mainly pertained to production and logistics related efficiency issues Thus, during the interviews, five interviewees highlighted the problems involved in trying to fulfill language-specific or customized products from an assembly facility located outside Europe

4 5 5 Supplier Relations

Table 4 20 Average score for questions regarding supplier relations

Q42	Level of integration of the company with its suppliers? Arm's length, strongly integrated or somewhere in between? (1 = arm's length relationship 7 = strongly integrated)	*6*
Q43	In those cases where the company integrates suppliers' new component technology to what extent are the development systems of both companies integrated? (1 = not at all 7 = strongly integrated systems (e g cross-organisational teams)	*5*
Q44	Prominence of goal in your sourcing strategy minimise inventories of parts/ increase frequency of deliveries (1 = receives no particular attention 7 = very important part of our strategy)	*7*
Q45	Prominence of goal in your sourcing strategy reduce inventories at suppliers (1 = receives no particular attention 7 = very important part of our strategy)	*6*
Q46	Prominence of goal in your sourcing strategy minimise chain cycle time (1 = receives no particular attention 7 = very important part of our strategy)	*7*
Q47	Prominence of goal in your sourcing strategy continuos improvement of supplier performance (1 = receives no particular attention 7 = very important part of our strategy)	*7*
Q48	Relevance of statement "There is a joint approach to total quality" (e g interaction and mutual agreements on quality targets) (1 = of no relevance 7 = very relevant)	*6*
Q49	Relevance of statement "There is transparency and open discussion of costs and a rational framework for determining costs, price and profits " (1 = of no relevance 7 = very relevant)	*6*
Q50	Information sharing with main suppliers inventory data (1 = no information sharing 7 = intensive information sharing)	*6*
Q51	Information sharing with mam suppliers current demand for end-products (1 = no information sharing 7 = intensive information sharing)	*7*
Q52	Information sharing with main suppliers demand forecasts (1 = no information sharing 7 = intensive information sharing)	*7*
Q53	Information sharing with main suppliers future product development projects (1 = no information sharing 7 = intensive information sharing)	*6*
Q54	Does your company make efforts to smooth production for its suppliers (limit the percentage change in the size of successive orders)? (1 = no effort 7 = intensive effort)	*3*
Q55	Company's policy with respect to supplier development/assistance (1 = no assistance at all 7 = we have a structural programme for assisting suppliers)	*5*
Q56	To what extent do you consider yourself the organiser of a production chain? 1 = to no extent 4 = to some extent (only involving a number of products) 7 = to a great extent)	*6*

Source postal questionnaire, 1999

In line with the textbook NHVP approaches, the supply chains of the focal companies were characterised by a combination of vertical ownership disintegration and vertical co-ordination integration The early microcomputer industry had been characterised by a fairly high level of vertical ownership integration and most computer makers were manufacturing their own proprietary component technologies (Langlois and Robertson, 1995) For example, in the early 1980s Apple, IBM and Digital manufactured most of its required components in-house, including motherboards, monitors and keyboards However, during the 1980s and 1990s nearly all focal companies had outsourced most component production The main exceptions were IBM and Intel At the time the first interviews were conducted IBM was still strongly involved in the manufacture of, *inter alia*, hard disk drives, semiconductors, displays and, to a lesser extent, motherboards for servers Intel, of course, remained strongly involved in the production of microprocessors, other semiconductors and motherboards The only other companies with in-house component production were Digital, Compaq and Apricot-Mitsubishi At the time the first interviews were conducted, all three companies manufactured some of their server boards in-house [11] However, both Compaq and Apricot-Mitsubishi had already outsourced most of their board requirements and by the time of the second interview, in 1999, neither company produced boards in-house

At the same time, the supply chains of the focal companies were not regulated merely by market forces but, instead, were characterised by a substantial degree of co-ordination integration In the postal questionnaire the companies were asked to rate the level of integration with the suppliers on a scale from one (arm's length) to seven (strongly integrated) The average score of six indicates a high degree of co-ordination integration (Q42) All respondents considered themselves as organisers of a production chain (Q56) Co-ordination integration concerned both the organisation of inbound logistics and, to some extent, the organisation of product/process development and ongoing technology issues

[11] At the time the first interviews were conducted Digital also still produced some of its own Alpha processors in the USA However, the company was in the process of outsourcing the production to Intel and one of its plants had already been sold (Oliver, 1999)

As regards logistics, many of the textbook JIT manufacturing principles also figured in the organisation of inbound logistics All focal companies were constantly sharing information with their suppliers regarding inventory data, current demand for end-products and demand forecasts (Q51–Q52) Goals such as the minimisation of component inventory, increasing the frequency of deliveries, minimisation of chain cycle time and continuous improvement of supplier performance figured prominently in the sourcing strategies of the focal companies (Q44–Q47) In fact, Apple had been one of the first American electronics firms to adopt a JIT supply philosophy (*International Business Week*, 14-05-84)

There was one important divergence from the textbook JIT supply system as outlined by Sayer (1986) As discussed in the previous section, the demand on the assembly lines of the focal companies was erratic and unpredictable and the focal companies made little attempt to smooth the demand on the production facilities of their suppliers (Q54) "Really the answer to the question [how do you try to smooth production for your suppliers?] is no, because we are very much demand based We don't deliberately try to smooth it We are driving our suppliers nuts We are trying to forecast but the mix does not come in as you expect it " (Interview Allen, Dell, Oct 1999) As explained in section 2 3 2, textbook JIT supply systems, characterised by a virtual elimination of inventories, cannot deal with a highly irregular and unpredictable sequence of pulls from the customers since this would lead to inefficient use of labour and machinery upstream, at the suppliers (Sayer, 1986) The next chapter will show what this meant for the inbound logistics pipelines of the focal companies

The textbook ideas regarding the co-ordination of product and process development were born out to some extent In line with the textbook Japanese Partnership and Lean Supply models (Lamming, 1993) outlined in section 2 3 2, most microcomputer makers had not only outsourced the majority of component production activities, but also the design of many components In line with the Lean Supply model, many microcomputer makers had given up control over parts that in the traditional Mass Production system would have been presumed to be the natural preserve of the assembler, notably microprocessors and operating systems However, in a sense, the process of component outsourcing had progressed one level further In fact, on the issue of product and process development, in relation to some components the network started to take on some characteristics of a decentralised network, rather than a core network (see section 2 3 2)

Langlois and Robertson (1995) argue that the industrial organisation in the microcomputer industry comes near to what they call a modular system One of the main characteristics of a modular system is that the rules of compatibility of individual components are standardised for the industry and publicly known, rather than laid down by individual lead assemblers As a result component innovation can proceed in an autonomous fashion In the microcomputer industry one of those standard interfaces concerns the modular bus architecture[12] According to Langlois and Robertson (1995) and Angel and Engstrom (1995) the standardisation of the bus since the mid-1980s reduced the need for co-ordinated technology development at the system level Component development could proceed in autonomous fashion as long as the suppliers made sure that their components maintained the ability to connect to the standard bus

Although their ideas were partly supported by the findings of the present study, the situation was not as extreme The focal companies gave evidence of substantial technical co-ordination with their suppliers The situation depended very much on the particular component concerned Furthermore, the fact that the focal companies were no longer leading the innovation process in relation to some components did not necessarily mean that there was no co-ordination

Thus, apart from the fact that companies like IBM and Intel were still heavily involved in the in-house production of component technology, nearly all companies were still the co-ordinators of the development of some components, notably motherboards, enclosures and in the case of some focal companies, power supplies and interconnect material As

[12] A bus is a collection of wires through which data is transmitted from one part of a computer to another The internal bus connects all the internal computer components to the central processing unit and main memory The expansion bus enables expansion boards to access the central processing unit and memory

regards the motherboards, although many companies used OEM-designed solutions for some low-end models, all focal companies retained a strong in-house development function for the design of higher-end motherboard models In the case of Intel based systems the design of the motherboards was to some extent controlled – the bus would be industry standard However, most focal companies were trying to differentiate their systems in terms of functionality and reliability, which meant that most companies had features on their motherboards that were different from the other companies Likewise, all companies retained a strong in-house development capability for the design of enclosures Although the chassis dimensions of some of the models were industry standards, all companies differentiated their products from those of their competitors by designing their own enclosure styles and bezels

The design of these components typically involved a substantial amount of technological co-ordination and information exchange As regards the boards, typically the engineers of the focal companies would carry out the electrical and physical (lay-out of the components) design using CAD tools while the subcontractors would be responsible for prototype production As regards the enclosures, typically the focal companies would be responsible for the industrial design drawings while the subcontractor would be responsible for the production of the tools and dies The development processes involved a substantial amount of communication between the partners involved, from the stage of conception to final test "Obviously we have to design to match their [the suppliers'] processes And they can suggest efficiencies as well They can say, if you change this and that it is going to be easier for our tool-makers" (Interview Higgy, IBM, July 1999) The process of tool-making for enclosures as outlined by one of the interviewees was a prime example of development activity taking place synchronously at suppliers and customers (Interview Higgy, IBM, July 1999)

As regards the majority of components where the innovation process was no longer led by the computer assembler, the development process still involved co-ordination integration In the postal questionnaire the respondents were asked to rate the extent to which their development systems were integrated with those of suppliers that delivered their own component technology (Q43) The average score of five indicates a fairly high level of integration

The interviews showed that the product development teams of all focal companies had a strong interface with the development teams of Intel Although Intel developed its microprocessors in a largely autonomous process, the company supplied early prototypes to the focal companies, which allowed these companies to do system development work The systems were heavily tested in both organisations The focal companies received assistance in the design of their products while Intel was able to resolve potential bugs before its processors went to the market Another reason for co-ordination concerned the customisation of otherwise industry standard components For example, some of the hard disk manufacturers carried out some company specific final configuration and sub-assembly activities for the focal companies and display manufacturers customised the colouring of the casings

Focal companies were also constantly exchanging information on future development projects with all of their (potential) suppliers (Q53) On a frequent basis the focal companies compared their own technology road map, outlining their ideas on future product offerings, with the component road map of the suppliers "It is a continuos process were we meet regularly talking about developments and going forward and looking at industry changes" (Interview Flynn, Gateway, September 1999)

Furthermore, new components could not simply be assembled in an existing computer system The introduction of every new component involved a certain integration effort and in some cases a great effort It involved a process of testing, evaluation and certification on the side of the assembler and it could even require motherboard redesign This process did involve a certain amount of communication between the engineers of the assembler and the suppliers

Finally, limited technological co-ordination continued to exist during the ramp-up of the computer production process (involving the new component) as well as later, during the entire life-cycle of the component Thus, some suppliers were heavily involved in the training of technical staff at the focal companies in the run-up to the production of systems involving the new components Furthermore, during the initial period of production of systems incorporating a new component, the production engineers were typically in contact with engineers of the suppliers and there existed a constant information exchange on issues such as component reliability and quality issues over the entire life-cycle of the component

The above shows that, in line with the textbook NHVP approaches and partly contradicting the ideas of Langlois and Robertson (1995), the innovation process still involved a substantial amount of co-ordination and information exchange between the focal companies and the component suppliers However, of particular relevance to the research questions, the involvement of the European operations in this co-ordination was more limited, partly a reflection of the limited R&D activities of the European operations, as described in the previous section In the groups involved in genuine microcomputer development, i e the European server development groups of IBM and Digital, and in Dell's *European Products Group*, the level of technological co-ordination was comparable to the level at the corporate design facilities and included all the elements mentioned above However, these relatively small development groups aside, the involvement of the European operations was limited

Thus, as regards those components where the innovation process was led by the focal companies, notably enclosures and printed circuit boards, the European operations were generally not integrated with the suppliers at the actual design stage Likewise, as regards those components where the product development process was no longer led by the computer assemblers, the involvement of European operations in technological co-ordination was limited

As outlined in the previous section, engineers in European operations did play a role in the corporate development process and were involved in discussions and evaluations of new parts However, at the design stage, it was typically the engineers of the corporate design facilities that communicated with the development engineers of the suppliers To support their input in the corporate development process, regional staff kept themselves informed regarding road maps and general technological advances in the supply base However, this generally took place at an informal level, as part of the day-to-day and periodic operational contact with suppliers (see below) "If a supplier came to us and developed a new product, all we could do was to get samples, submit them to The States and get them approved or not" (Interview Kiely, AST, Oct 1999) Furthermore, this integration tended to involve the European sales and marketing groups more than the manufacturing engineers

At most, local engineers were involved in the ramp-up of the suppliers' production facilities, notably production facilities located in Europe This could involve activities such as managing engineering change orders, the introduction of an existing tool to a regional supplier and process qualification However, even in these situations, as far as technical issues were concerned, local engineers often played only a supporting role, facilitating and joining meetings between corporate engineers and supplier engineers

The exceptions included less strategic items, such as packaging, electronic and printed documentation kits, certain cables, screws, fasteners, labels, etc In these cases the technological co-ordination and information exchange was typically handled entirely by the European operations Some of these items, involved a very limited amount of technological co-ordination but regular changes in packaging, foam and cables involved a substantial engineering interface The supply of hard disk drives could involve a limited amount of co-ordination integration where the supplier carried out limited, additional, subcontracting activities for some of the focal plants

Co-ordination between European operations and suppliers continued in relation to day-to-day operational issues, which could involve technical issues Thus, supplier quality engineers in operations were in regular communication with the suppliers for failure analysis and the discussion of general quality issues and staff training Furthermore, technical and quality issues figured prominently in discussions with suppliers during the periodic supplier reviews organised by the European operations

Returning to the corporation as a whole, textbook NHVP models prescribe a strong rationalisation of the supply base (Lamming, 1993, Womack et al, 1990) In line with this all focal companies worked towards a reduction of the number of suppliers per component model, a company-wide consolidation of purchases and an elimination of input requirements All focal companies practised single sourcing for many component models – although, they could have several suppliers producing similar components (see section 5 2) However, the reasons were not necessarily restricted to the textbook idea of facilitating partnership with suppliers In some cases focal companies were forced to single source components, simply because of the fact that demand for systems was driven by a particular component technology or brand that was available from one source only, e g in the case of sound and video cards and microprocessors

The focal companies typically retained a dual or multiple sourcing strategy for a number of more industry-standard component models such as memory, floppy drives, capacitors and resistors In conflict with the textbook NHVP approaches, this strategy was partly driven by the traditional, Fordist, aim to create negotiating leverage or prevent supply problems associated with single sourcing However, often an important reason lay in the fact that a single supplier could simply not fulfil the demand of a focal company Again somewhat at odds with textbook NHVP, the research also found evidence of parallel sourcing (Hirakubo and Kublin, 1998, Langlois and Robertson, 1995) Although many component models were single sourced, the focal companies protected themselves against opportunism or supply problems by using different suppliers to supply similar components Thus, focal companies typically received hard disk drives and enclosures from several suppliers, all supplying a particular model The existence of working relations with several suppliers and the similarity of the components meant that the focal companies could switch from one supplier to another without great difficulty

As regards the company-wide consolidation of purchases, virtually all purchases of strategic material inputs for the various plants of the focal companies were consolidated As discussed in section 4 5 4, in most cases supplier selection involved global procurement groups and global commodity managers were awarding contracts to supply the various plants of the company The main exceptions involved media, packaging material and a number of c-class items such as printed labels, although some companies were consolidating the purchases for some of these items as well For example, Industrial Print in Ireland supplied printed logos to Dell's world-wide manufacturing plants and Ire-Tex was contracted to supply packaging to Dell's plants in Ireland as well as in the Far East Similarly Smurfit supplied packaging to Gateway in Ireland as well as in the USA

As regards the elimination of input requirements, the earlier mentioned strategy of component modularization led to a substantial reduction in the necessary components and the number of suppliers The number of suppliers was further reduced by the use of system integrators, contracted to carry out the sourcing and higher-level assembly of components The practice was partly driven by (Fordist) production cost consideration – companies were able to negotiate costs with the system integrators that were lower than the costs involved in in-house production (Interview Tyldsley, Digital, Feb 1999) However, in the spirit of textbook NHVP approaches, the practice was mainly driven by a desire to reduce the cost of managing the supply base – the cost of ordering, invoicing, etc

One example involved the supply of system enclosures Traditionally, plastic and metal components of the enclosure were sourced from different suppliers, specialising either in the area of metal work or plastic moulding However, in the second half of the 1990s, computer assemblers were increasingly looking for integrated suppliers able to supply the total enclosure and specialised suppliers were replaced by integrated suppliers [13]

[13] Some indigenous specialised companies, such as Fullarton in Scotland, extended their internal capabilities and diversified into integrated enclosure suppliers Other companies initially attempted to answer the new requirements via strategic alliances Thus, in Ireland, a metal engineering company, Ballymount, and two indigenous plastic companies, Rennicks and Top Tech, formed a joint-venture called Orbitech to supply integrated enclosures (Kennedy, 1998) Similarly, up to 1998, Southborough, a metal

Furthermore, the enclosure suppliers were requested to take care of the sourcing of parts and the sub-assembly into the enclosure Thus, an enclosure was typically supplied with brackets, floppy drive, power supply and some internal cables already fitted The enclosure for the storage systems typically came in with the backpanel (an interconnect circuit board) and some cabling already assembled Other examples of the elimination of linkages involved the higher-level assembly of components onto the hard disk drive and the sourcing/kitting of components for the accessory boxes (for further detail see section 5 2)

Finally, in line with the textbook NHVP concepts, the interviews revealed substantial supplier development/assistance activities in all focal companies, although the level of assistance depended strongly on the particular component or supplier involved (see also Q55) More detailed information on supplier development and its effects will be provided in section 5 7

4 6 Conclusions

This chapter started with an overview of the global microcomputer industry and a brief history of the promotion and development of the industry in Ireland and Scotland It was shown that the global and Western European PC industry have always been dominated by USA based firms that competed on a global scale from an early stage The main microcomputer players typically supported their global competition strategies with a global manufacturing presence In 1998, nearly all focal companies had at least one microcomputer assembly and test facility to serve each of the triad regions North America, Europe and the Far East Within Europe, Ireland and Scotland were clearly a preferred base for microcomputer production

The histories of the microcomputer industry in Ireland and Scotland show many similarities Although the countries had a different industrial history, during the 1970s

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fabrication company, and Datapackaging, a plastic moulding company, co-operated in a joint-venture called Unisol (Dunne, 1998) and 1980s both countries were semi-peripheral regions suffering from high unemployment and in both countries foreign direct investment was seen as a vehicle for restructuring the economy Industrial development agencies in both countries quickly identified the data-processing industry as an imported sector for targeted foreign direct investment promotion The promotion package in both countries included financial and fiscal incentives, low wages and access to the European market although Ireland had a far lower corporation tax while Scotland could offer access to a greater home market The microcomputer assemblers sourced a very small proportion of material inputs in the local economy In the early 1980s this was increasingly seen as a missed opportunity and industrial development agencies in both countries attempted to increase local linkages through the development of indigenous suppliers as well as the attraction of foreign-owned suppliers Rising wage rates during the 1990s meant that the microcomputer hardware industry in both countries came under increasing competitive pressure from low cost locations in the Far East

By 1998, both Scotland and Ireland had a sizeable microcomputer hardware industry Both countries had half a dozen main microcomputer assemblers, nearly all foreign owned Both countries were each producing over one third of the PCs sold in Europe while Scotland was also responsible for 60 per cent of Europe's workstations and 68 per cent of electronic notebooks System assemblers employed around 9,000 workers in both countries, while at peak periods employment rose well above this figure The amount of local linkages remained disappointing Since the mid-1980s both countries had seen the creation of a number of indigenous companies and inward investment by foreign owned MNEs able to supply the microcomputer assemblers However, many of the local linkages created in the 1980s and early 1990s disappeared in the 1990s when, due to increasing wage-pressure, many suppliers ceased producing low-tech inputs in Ireland and Scotland

The main part of the chapter concerned the extent to which the microcomputer industry matches the textbook picture of NHVP The detailed analysis of the elements of the value chain showed that the microcomputer industry had many characteristics of textbook

NHVP approaches – notably Lean Production/ Lean Supply (Lamming, 1993, Womack et al , 1990), Mass Customisation (Pine, 1993), Time-Based-Competition (Stalk and Hout, 1990) and JIT/TQM (Sayer, 1986) – although important elements were not fully born out Here I will reiterate a number of issues that will prove particularly important for the analysis of the geographical configuration of the supply network and the organisation of logistics in Chapter 5

As regards the production function, the focal companies had all adopted the general NHVP-related production management philosophies The central principle of the JIT philosophy, i e , only doing work when needed, in the necessary quantity at the necessary time, was followed out right to the front end of the production process by adopting a BTO model, combined with short order lead times for at least part of the output There was, however, one important difference from the textbook JIT manufacturing process which, was largely a consequence of the market conditions faced by the microcomputer companies The market for microcomputers was characterised by strongly fluctuating and unpredictable demand In such an environment a BTO strategy in combination with very short lead times resulted in a strongly fluctuating and unpredictable demand from final assembly on upstream functions A textbook JIT manufacturing system cannot deal with highly irregular and unpredictable pulls from final assembly since it would lead to inefficient use of labour and machinery upstream (Sayer, 1986) In the focal factories this problem was partly solved by reducing the number of phases in the assembly process As a result, the first upstream activity to be encountered was component production which virtually all took place outside the boundaries of the focal plants

As regards corporate organisation and subsidiary roles, the focal companies had many characteristics of Womack et al 's (1990) post national company and the system of multiregional production Thus, nearly all focal companies had at least one assembly facility in each of the triad regions Apart from manufacturing, the European operations typically included substantial sales and marketing, service and regional headquarter functions The organisation structure of the focal companies was characterised by a combination of centralisation and decentralisation However, one important deviation from the system of multiregional production and the post-national company was the lack of substantial local-for-local R&D groups in the European operations Partly because of a relatively low level of product differentiation for specific geographical markets, the regionally specific product development requirements were relatively small and the microcomputer development facilities were strongly concentrated in the companies' home countries

Finally, as regards supplier relations, in line with the textbook NHVP concepts, the supply chains of the focal companies were characterised by a high degree of vertical ownership disintegration and, at the same time, not regulated merely by market forces but characterised by a substantial degree of co-ordination integration Co-ordination integration concerned both the organisation of inbound logistics and, to some extent, the organisation of product/process development and ongoing technology issues

As regards logistics, many of the textbook JIT manufacturing principles also figured in the organisation of inbound logistics However, there was one important divergence from the textbook JIT supply system, strongly related to the above mentioned market conditions and the BTO strategy adopted by the focal companies As discussed, the focal companies were serving erratic and unpredictable demand with a BTO strategy and made no attempt to smooth the demand on the production facilities of their suppliers Again, a JIT supply system, characterised by a virtual elimination of inventories, cannot deal with a highly unpredictable sequence of pulls from the customers As explained in the next chapter, this is one of the reasons why the supply chain of most components involved certain (tightly managed) buffer inventories

As regards the inter-firm co-ordination of product and process development, in line with the textbook Japanese Partnership and Lean Supply models (Lamming, 1993) most microcomputer makers had outsourced the majority of production as well as the design of many components and many focal companies had given up control over parts that in the traditional Mass Production system would have been assumed the natural preserve of the assembler One might argue that the process of component outsourcing had progressed one level further since in relation to some components the network started to take on some characteristics of a decentralised network, rather than a core network In relation to this Langlois and Robertson (1995) and Angel and Engstrom (1995) argue that the organisation in the microcomputer industry comes near to a modular system In such a system there is a strongly reduced need for co-ordinated technology development and component development can proceed in an autonomous fashion

The findings presented in this chapter show that the situation in the focal companies was not as extreme and depended very much on the particular component concerned Thus, nearly all companies were still the co-ordinators of the development of some components Furthermore, where the computer assembler no longer led the innovation process, the development process still involved a substantial amount of co-ordination integration and technical information exchange However, the involvement of the European operations in this co-ordination was more limited, partly a reflection of the above mentioned limited R&D activities of the European operations At the design stage, it was typically the engineers of the corporate design facilities that communicated with the development engineers of the suppliers, except in the case of less strategic items Obviously, as will be discussed in the next chapter, this limited involvement of the European operations in the inter-firm co-ordination of product and process development has important consequences for the relevance of the argument for spatial proximity in NHVP industries in non-core regions

CHAPTER 5 GEOGRAPHICAL CONFIGURATION OF SUPPLY CHAINS AND THE ROLE OF BUYER-SUPPLIER PROXIMITY DRIVERS

5 1 Introduction

This chapter investigates the relevance of the four research patterns as outlined in Chapter 2 The chapter starts with a detailed account of the geographical configuration of the supply networks of the microcomputer assemblers in Ireland and Scotland Building further on data presented in Chapter 4, the following section asks to what extent the selection of suppliers with production facilities in Ireland and Britain was driven by the two NHVP-related buyer-supplier proximity drivers identified in Chapter 2 efficient technical information exchange and logistical efficiency Section 5 4 provides a detailed account of the way focal companies had structured their inbound pipelines This facilitates an appreciation of the key logistics data in section 5 5 that serve to establish whether the geographical configuration of the supply networks came about in the context of an optimal or a sub-optimal inbound logistics system, again building on insights presented in Chapter 4 Next, section 5 6 presents information on the relevance of other NHVP-related issues that, in theory, might have shaped the geographical configuration of the supply networks of the microcomputer companies

Up to an including section 5 6 the chapter focuses on static indicators of regional development, notably the proportion of material inputs sourced from the local and regional economy and the number of local linkages Section 5 7 describes the more dynamic development effects of the focal companies on the local supply base in Ireland and Scotland The conclusion is used to match the empirical pattern with one of the research patterns outlined in Chapter 2 The discussion of the findings in the context of the existing theory will follow in the overall conclusions of the dissertation

5 2 Source of Supplies of the Microcomputer Assemblers

In this section the sources of the parts and components used by the focal companies will be outlined The data are primarily based on interviews with materials managers conducted in the eleven focal companies in the period 1998-1999 In the first round of interviews, interviewees were shown a list of generic component categories, supplemented with categories more specific to the company[1] Interviewees were asked for the name and location of their suppliers as well as the geographical origin of the parts and components supplied As extra check, interviewees were shown a list of existing component manufacturers in Ireland and Scotland and were asked if the list included any other suppliers Great care was taken to establish the actual location of end-product manufacturing plants, rather than the location of the suppliers' headquarters, logistics facilities or component plants Information was checked with information on suppliers obtained from other sources (mainly newspapers, company web-sites and other internet sources) Discrepancies were addressed during the second round of company interviews, conducted during the second half of 1999 Furthermore, telephonic interviews were conducted with selected suppliers to clear up remaining queries, notably in relation to multi-plant suppliers and the activities in their various plants

The principal aim of this section is to provide a general overview of the geographical origin of the material inputs used by the focal companies Partly in support of section 5 7, on the dynamic indicators of development, this section provides insight into the 'nationality' of the supplying companies In relation to the suppliers located in Ireland and Scotland the names of the suppliers are provided as well Separate tables containing more detailed information regarding the precise location, name, nationality, activity and relative importance of the various suppliers of individual focal companies were compiled to support data analysis An example of such a table has been included in Appendix C Tables for all focal companies are available on request In Appendix D focal companies and regional suppliers are included in one single table which allows for a better

[1] The addition of more specific components was based on information provided in the web-sites of the focal companies

interpretation of the importance of individual suppliers in the regional supply network Furthermore, this table provides more detailed information regarding the geographical location of suppliers in Ireland, Scotland and Wales The list only includes suppliers and sub-contractors that were actually manufacturing or assembling locally The data in the text and the appendixes refer to the situation at the time the first round of interviews was conducted – between the end of 1998 and the start of 1999 – unless different periods are specifically indicated [2]

The sources of parts and components are discussed under a number of generic component categories The first section deals with the suppliers involved in the assembly of complete computer systems The following sections deal with the components sourced for actual system assembly metal and plastic components, motherboards and backpanels, microprocessors, memory, storage drives, power supplies, heatsinks and cooling fans, batteries and AC-adapters, modems and network components, graphics, video and sound cards, cables, screws and other c-class items This is followed by sections dealing with computer peripherals displays, keyboards, mice and joy-sticks, printers, scanners and digital cameras, speakers and microphones, docking stations Next there are sections on media, kits, packaging material and sub-assembly services Four companies were still assembling a limited range of motherboards on-site – an activity that involves a great number of components and suppliers The sources for these components will be dealt with under four generic headings etched circuit boards, semiconductors, passive components, surface-mount-interconnect The final section provides a summary of the location of the suppliers

5 2 1 Complete Computer Systems

Most computer companies outsourced the manufacture or assembly of some of their world-wide system offerings, although only five companies used contractors to supply systems for the European market Such outsourcing always involved the lower end

[2] The interviews with Intel and AST staff members were conducted on a post-hoc basis with reference to the first half or 1998

models, although Apricot also outsourced one of its three server models Companies had various arrangements with their outsourcing partners At one end of the spectrum, suppliers were supplying on a 'full-turnkey-basis', i e they were responsible for the manufacture as well as the design of a particular model, although customers would typically have a strong involvement in the design At the other end of the spectrum, suppliers would be employed using a more traditional subcontracting model, involving the assembly of components issued free of charge by the contractor to the subcontractor

Focussing on the European market, Compaq had some of its lower-end desktop and portable computer models manufactured on a full-turnkey basis by three corporate Taiwanese suppliers Most models were manufactured in Taiwan, although one company, Inventec, had started assembly operations in a facility near Compaq in Scotland IBM had a global partnership with a Taiwanese supplier to manufacture lower-end home computers on a full-turnkey basis in a facility in The Netherlands A Scottish company, Fullarton Computer Industries, assembled low-end models in a facility near IBM This involved a more traditional subcontracting model with Fullarton pulling most materials from IBM's logistics system

Sun's network computers for the European market were manufactured in England by Canada based Celestica, a global partner of Sun The systems were designed by Sun but Celestica had taken the product from there and managed the supply chain The entry-level desktop computers were manufactured on a full-turnkey basis by Taiwan based Mitac in England Part of Apple's portable computers was manufactured on a full-turnkey basis in Taiwan by another Taiwanese company A more traditional arrangement existed with USA based APW/Horman Electronics that assembled desktop models on a free-issue basis in a facility located near Apple in Cork The facility basically functioned as a flexible extension of Apple's own plant Finally, Intel in Puerto Rico manufactured some of Apricot's server models on a full-turnkey basis

5 2 2 Metal and Plastic Parts

Metal and plastic parts mainly involved enclosures and racks Smaller items included sheet metal brackets and plastic parts for hardware subassembly Traditionally, plastic and metal components were sourced from different suppliers, specialising either in the area of metal work or plastic moulding However, as part of the strategy of linkage reduction (see section 2 3 2), focal companies were increasingly looking for integrated suppliers able to supply the total enclosure Furthermore, the enclosure suppliers were requested to undertake the assembly of additional parts into the enclosure, on a turnkey basis (i e the assemblers managed the assembly as well as the sourcing of the additional parts) Thus, an enclosure was typically delivered with brackets, floppy drive, power supply and some internal cables already fitted The housing for the data storage systems typically came in with the backpanel (an interconnect circuit board) and some cabling already assembled The level of sub-assembly could be very high in the case of the portable computers Three companies received enclosures for the portables with the screen and the motherboard already assembled However, the level of pre-assembly differed from company to company and some focal companies assembled the portable computers from scratch

The computer assemblers typically used two suppliers for their high volume enclosure models, while the supply of less current models, laptop enclosures and racks typically involved another two to five suppliers, depending on the volumes and variety required Individual models were either single or dual sourced, i e assemblers used one or two single suppliers for a particular enclosure model However, the main suppliers often supplied more than one model At the time the first interviews were conducted system enclosures were supplied by a substantial number of companies Suppliers mentioned included three Irish, two Scottish, eleven USA based, five Taiwanese, two Japanese and one Korean company as well as two other Far Eastern based companies

A large part of the high volume enclosures was manufactured regionally Five of the focal companies had all their high volume enclosures manufactured in the same country,

, while two other focal companies sourced a large part of their volume models locally Four companies sourced all their volume models from suppliers located overseas, but two of these focal companies, Gateway and Packard Bell-NEC[3] were both in the process of organising a local source for their volume models As regards the regional sources, focal companies in Ireland received volume enclosures from the local facilities of three indigenous companies (Datapackaging, Top Tech, Ballymount) and three foreign MNEs (LMS-Beach, CTM-Southborough, Munekata) One focal company sourced part of its enclosures from a supplier in Scotland (Fullarton) The focal companies in Scotland received volume enclosures from the local facilities of four indigenous companies (Fullarton, High Speed/APW, Livingston Precision, Fife Fabrications) and four foreign MNEs (Bermo, McKechnie, Foxteq and Birkbys/Marubeni) Two focal companies sourced part of their volume enclosures from suppliers in Ireland (C-Fab/APW and Fullarton[4]) The imported volume models were nearly all supplied by Asian companies and manufactured in the Far East, typically in Taiwan and China Packard Bell and Intel were the only companies that imported part of their volume models from other regions, notably the USA and France

Lower volume enclosure models tended to be manufactured in the USA and in some cases in Ireland (C-Fab/APW) or Scotland (Fullarton) Because of the low volumes involved, a number of companies sourced low volume server and workstation enclosures[5] from the same plants that supplied the sister facilities in the USA

The supply of server racks involved eight USA based companies and two UK based companies Again, because of the low volumes involved, these items were often sourced from the same factories that supplied the corporate facilities in the USA Thus, four focal companies imported all racks from the USA, while three companies received enclosures

[3] Packard Bell had already decided to source all its volume models from Fullarton Computer Industries in Scotland
[4] In 1999, Fullarton invested in a manufacturing plant in Limerick with the hope of supplying Dell In the mean time, the plant was used to supply one of Fullarton's existing customers in Scotland IBM However, the Dell business never developed, and two years after opening, Fullarton Limerick closed (Interview Kennedy, Enterprise Ireland, Dec 2000)

manufactured in the USA as well as Scotland (Fullarton), Ireland (CTM/Southborough) or England (Retal) Because of their bulky nature, in two cases the imported server racks were shipped in flat-pack form, while a local turnkey company (Brands and Livingston Precision) took care of the assembly, before delivery to the focal company

All enclosures for portables were imported from outside Ireland or the UK Three focal companies sourced partly assembled portables from established Asian portable computer manufacturers All these items were manufactured in Taiwan, Korea or Japan Three other focal companies sourced enclosures for portables from specialised plastic moulders Suppliers included USA based, Japanese and Singaporean companies and the enclosures were manufactured in the USA, Belgium, Japan and Singapore

Finally, although most small metal brackets and plastic components came integrated with the enclosures, most focal companies sourced a small number of these items separately Suppliers mentioned included seven USA based, three Irish, two UK based and one Japanese company Focal companies in Ireland received material from plants in Ireland (CTM/Southborough and Rennicks) Focal companies in Scotland received material from Ireland (Ballymount, APW/C-Fab and CTM/Southborough), Scotland (Fife Fabrications, Birkbys and McKechnie) as well as from four sources in the USA

The above provides a snapshot of the linkage situation at the time the interviews were conducted Since the mid-1990s the local enclosure supply industry has been in a state of flux, partly due to the NHVP-related supply chain strategy of corporate consolidation of purchases Some indigenous companies successfully internationalised by investing in other markets, as in the case of Scottish based Fullarton However, the main result has been that the focal companies' existing suppliers set up production operations in Ireland and Scotland, often before business was guaranteed In some cases this involved new

[5] Not all server and storage system models were low volume Thus focal companies with a large server and data storage system business, such as Sun, Digital and IBM, used these enclosures in high volumes and typically sourced them locally

green-field investments[6], in other cases global contract electronic manufacturers (CEMs) simply acquired indigenous companies to establish a local presence[7] Partly as a result of these dynamics, the linkage situation has changed substantially since the time the first interviews were carried out Particularly in Ireland, a number of smaller indigenous companies have been replaced by local subsidiaries of larger CEMs

5 2 3 Motherboards, Backpanels and Riser Cards

Every computer system includes a motherboard and many contain a riser card to slot in the expansion boards Backpanels are the connector boards used in data storage systems In the period the first interviews were conducted, nearly all computer assemblers in Ireland and Scotland outsourced all of their board requirements Only IBM, Compaq, Apricot and Digital still manufactured high-level server boards on-site, but even these four companies outsourced most of their volume board requirements

Focal companies dealt with a limited number of suppliers at a time Computer makers typically used one to three suppliers for their volume models while a number of companies dealt with one or two other suppliers for backpanels and riser cards Most boards were sourced under corporate contract from global CEMs, operating multiple production facilities world-wide Suppliers included eight USA, three Taiwan, two Hong Kong, one Singapore, one Canada and one Japan based company The only indigenous supplier involved was Scottish CTS, that assembled backpanels for Digital

[6] Thus, in 1998, American LMS-Beach invested in a large integrated production facility in Ireland to supply Dell, gradually replacing Southborough and Datapackaging, two indigenous suppliers that had formed a joint-venture to supply Dell with integrated enclosures (AMT, May 1998) Taiwanese Foxteq set up a new enclosure plant in Scotland and, since the interviews were conducted, the same company invested in a new Irish facility to supply Apple (Oliver, 1999)

[7] In 1997, APW, a large USA based CEM, took over the metal stamping plant of C-Fab in Dublin and the electronics assembly facilities of Horman in Cork in 1997 (*AMT*, June 1997) One year later the company acquired the High Speed production facilities in Scotland and England Similarly, in 1998, Southborough, still then a Dell supplier, had been acquired by CTM, a global USA based CEM In the same year Trend Technologies another USA based enclosure builder, took over the metal operations of Ballymount as well as the plastic moulding plant of Datapackaging (Interview Kennedy, Enterprise Ireland, Dec 2000)

As regards the geographical origin of the boards, Intel operated a printed circuit board assembly (PCBA) facility in Ireland until the second quarter of 1998 This meant that, prior to that time, a substantial part of the board requirements of the microcomputer companies in Scotland and Ireland was manufactured in Ireland, although supplies could also come from Intel's other board assembly facilities in Malaysia or Puerto Rico, as well as from the facilities of its CEMs, typically located in South-East Asia (Interview Nagle, Intel ESSM, November, 1998)

At the time the interviews were conducted, Intel had already ceased PCB assembly in Ireland The geographical configuration of motherboard supply linkages differed from company to company Three companies, Apricot, Packard Bell-NEC and Intel itself, exclusively used Intel boards and therefore received all their boards from South-East Asia or Puerto Rico[8] Similarly, Gateway, IBM, Compaq and Apple imported nearly all their motherboard requirements, while AST and Digital used both imported and locally manufactured motherboards At the other end of the spectrum, two computer assemblers, Dell and Sun, sourced virtually all volume motherboard requirements from plants in Scotland, the North of England and, to a lesser extent, Ireland The main sources for imported boards were Taiwan and China while other sources included the USA, Malaysia, Singapore, Mexico, and, more recently, Eastern Europe [9]

As regards suppliers in Ireland and Britain, computer assemblers were not restricting themselves to sources in the same country Thus, assemblers in Ireland used suppliers in Scotland (Solectron and Jabil), The North of England (Celestica) and, to a lesser extent, Ireland (MSL and SCI) Similarly, assemblers in Scotland used suppliers in Scotland (Solectron, CTS and Avex) as well as the North of England (Celestica) Two of the board suppliers in Scotland (Solectron and CTS) carried out other assembly activities for their

[8] The interviews with Intel and AST were conducted post-hoc with reference to the first half of 1998, just before the closure of Intel's system and board assembly plants In this period, both the Intel microcomputer plant and the AST plant received some of their board requirements from Intel's board assembly plant in Ireland

[9] Furthermore, countries like Taiwan, Korea, Japan and Singapore are important sources of boards for portable computers As discussed earlier, most of these boards are sourced as part of a pre-assembled system

customers, involving the integration of on-site produced backpanels, along with other components, into data storage systems

5 2 4 *Microprocessors*

Eight computer manufacturers in this research were manufacturing Intel based platforms Six of these companies were using exclusively Intel processors, while Compaq used a small amount of AMD processors as well Interviewees were not fully informed as to the actual location of production From 1998 to June 1999, Intel operated a Pentium cartridge packaging[10] plant in Ireland, and some Intel microprocessors used by the focal companies were packaged at this plant (Interview O'Farrel, Intel cartridge plant, April 1998) However, the focal companies typically used around 10 different Intel microprocessors and the Leixlip facility could supply three or four at most According to the interviewees, the majority of Intel processors came from various other plants of Intel's integrated world-wide production base, including plants in Malaysia, the Philippines, the USA and Puerto Rico According to Intel staff, most of the Intel chips were packaged in Malaysia, The Philippines and Puerto Rico (Interview, Smith, Intel Fab 10 and 14, July, 1998) AMD processors were packaged in Malaysia or Thailand

Three other computer makers were using proprietary processor technology Apple's processors were manufactured in the USA by its USA based strategic partners Digital's Alpha processors were manufactured by Digital and Intel in the USA[11] Finally, the microprocessors used by Sun were packaged in Canada and England by Celestica, its Canada based CEM partner

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[10] Packaging involves the assembly of the casing and interconnections onto the individual semiconductor die

[11] To solve a patent dispute, Intel had bought one of Digital Equipment s chip making operations in the USA (*The Irish Times*, 29-10-97) and supplied Digital with Alpha chips in 1998

5 2 5 Memory

Memory had become a commodity with little differentiation among products Most computer makers used several suppliers for memory The main suppliers mentioned in the interviews were Korean, Japanese and American companies with the required financial resources for this capital intensive industry Interviewees were not always informed as to the exact location of manufacturing, but the vast majority of the memory requirements was manufactured in Korea and Japan Smaller amounts were manufactured in the USA, Italy, Germany and Scotland (Motorola and NEC) Finally, one memory supplier had contracted a Scottish turnkey company, Sonnel, to carry out some value added work (reflash) on memory chips for Compaq

5 2 6 Storage Drives

Hard disc drives had already become largely a commodity product Most lower-end drives were industry standard products A number of vendors were providing value-added services such as the configuration with customer specific firmware However, suppliers were more and more driving their customers to a different model At least for the low-end drives, the trend was towards the supply of standard drives while the configuration was left to the customers or their subcontractors (Interview Murphy, Quantum, April 2001) Computer assemblers typically spread their requirements over four, or even more, of the main global suppliers The four most mentioned suppliers were all USA based multinationals The only non-American suppliers involved two Japanese companies that both figured less prominently

As regards the location of manufacturing, up until mid-1998, a substantial part of the hard disk drives were manufactured in Ireland and Britain Quantum, Seagate and Western Digital were all manufacturing drives in Ireland, while IBM assembled hard disk drives in the UK However, by the time the interviews were conducted, nearly all hard disk drives were manufactured, and in some cases configured, in the Far East, notably Singapore Both Western Digital and Seagate had consolidated production in Singapore, while IBM had relocated its production to Hungary in 1997 Only part of Quantum drives were still manufactured in Ireland Quantum's generic drives were actually manufactured by its Japanese partner in Ireland, Singapore and Japan[12] while Quantum's own facility was involved in customisation activities such as the configuration with customer specific firmware or, for two customers, the assembly of plastic components Seagate in Scotland undertook similar activities for Digital[13] Since the first interviews were conducted, the one remaining hard disk drive manufacturing plant in Ireland, MKIR Panasonic, has been shut down (Keogh, 2000)

As regards floppy disk drives, nearly all computer assemblers sourced their floppy disk drives from one or two Japanese suppliers Only one focal company used a Taiwanese supplier All floppy disk drives were manufactured in the Far East As regards CD-ROM and CD-ROM combo drives, the focal companies typically used one to three suppliers All CD-ROM drives were imported from the Far East The main suppliers were all Japanese companies Only two focal companies also used a non-Japanese supplier (USA and Korea) At the time the first interviews were conducted, only three computer makers used small amounts of CD-RW drives, all manufactured in the Far East Six focal companies were offering DVD drives Again, the suppliers mentioned in the interviews were all Japanese and all drives were manufactured in the Far East Five companies sold small amounts of Iomega Zip drives manufactured under licence by NEC in the Far East

Eight computer assemblers required small volumes[14] of higher capacity tape drives or complete tape libraries and autoloaders Suppliers mentioned included five USA based companies, one Norwegian and one Japanese company The lower-end drives were

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[12] Quantum had licensed Japan based MKE to manufacture Quantum's drives for the global market MKE was manufacturing Quantum drives in Japan, Singapore and at its Irish subsidiary, MKIR The type of drives manufactured at MKIR changed on average twice a year However MKIR was a single-product plant, producing one type of drive at a particular time The other drives were imported from Japan and Singapore (Interview Murphy, Quantum, April 2001)

[13] Both Seagate and Quantum carried out final configuration of drives, respectively in Scotland and Ireland Furthermore, for Digital they assembled high capacity hard discs into storage building blocks to be integrated in Digital's data storage systems (using plastic components supplied by Birkbys in Scotland) However, the arrangement had come to an end in the second quarter of 1999 when Digital carried out the subassembly on-site Quantum carried out similar assembly activities for IBM

[14] The largest volumes were required by companies with a strong data storage system business, i e Digital, Sun, IBM

manufactured in the Far East Higher-end tape drives and autoloaders were manufactured mainly in the USA, the Far East and Norway, while USA based Hewlett Packard manufactured tapes for Sun Microsystems in Bristol

5 2 7 Power Supply

The power supplies, particularly for the lower-end systems, were in many cases assembled into the enclosure by the enclosure or rack suppliers or a local turnkey company although some focal companies assembled all power supplies on-site (see under metal and plastic parts) As regards the low-end systems, computer companies typically used one or two suppliers Suppliers included mainly USA and Taiwanese companies as well as one Japanese company However, all low-end power supplies were manufactured in the Far East, notably China, Malaysia and Thailand

The higher-end power supplies were often specific to a particular server or data storage model, and manufacturers of high-end servers used up to five different suppliers, depending on the technologies required Suppliers mentioned included seven specialised USA based companies as well as a Japanese and a Swiss company Again, part of the higher-end power supplies were imported from the Far East, however the largest amount came from the USA, while Mexico, Germany, Austria and Italy also figured One company, Digital, received a small amount of high-end power supplies manufactured in England by USA based Unipower

5 2 8 Heatsinks and Fans

The heat dissipation of the low-end systems was typically managed by the integrated power supply cooling fan However, higher-end systems were characterised by higher heat dissipation and required additional cooling in the form of heatsinks and auxiliary fans In some cases the heat sink and fan came assembled as a unit Heatsink supply mainly involved USA based and Taiwanese companies although one UK based company, Redpoint, was an important supplier for three focal companies Most heat sinks were manufactured in the Far East, notably Taiwan, and to a lesser extent the USA but two companies received most of the heat sink requirements from two suppliers in England, Redpoint and Aavid Since the time the first interviews took place, these UK-linkages have ceased to exist when Aavid first acquired Redpoint (*Spirent* [online], 24-08-99, www spirent com/news/756 html), and later closed its UK manufacturing facilities (*Businesswire* [online], 31-03-00, www businesswire com)

Again most cooling fans came integrated with the power supplies or heatsinks As regards the auxiliary cooling fans, low-end fans were sourced from Japanese and USA based companies and manufactured mainly in the Far East A small number of focal companies used high-end auxiliary fans sourced from a small number of Japanese, USA and German companies and manufactured in the Far East, the USA, England (USA based McLean) and Germany

5 2 9 Batteries and AC-adapters for Portable Computers

Interviewees were not always fully informed as regards the origin of batteries and external AC-adapters for the portable computers partly because of the fact that in three cases the sourcing was managed by the suppliers of the sub-assembled notebooks The main battery suppliers mentioned were Japanese and, to a lesser extent, USA based companies Almost all batteries were manufactured in the Far East, notably in Japan Only IBM imported batteries from both Japan and Mexico Similarly nearly all external AC-adapters were manufactured in the Far East, notably in China and Malaysia

5 2 10 Modems and Network Components

For the systems where the modem chip was not integrated on the motherboard, computer companies offered modem cards and external modems as an option Modem cards and small amounts of external modems were sourced from two USA based companies, one

Taiwanese and one Japanese company Furthermore small amounts of modem PC cards for portables were sourced from two USA based companies, one Japanese and one UK based company (Psion) Most modem supplies were manufactured in the Far East, the USA and Mexico Part of the internal modem cards and modem PC cards for portables were manufactured in the Irish facilities of 3-Com However, according to the interviewees, most of the 3-Com supplies were manufactured in other 3-Com facilities [15] Finally, one of the focal companies sourced modem PC-cards manufactured by Psion in England

For systems where network chips were not integrated on the motherboards, or in case customers had specific requirements, the focal companies offered a range of network cards At the time the interviews were conducted, the network business was still very dynamic, involving a great number of regularly changing suppliers The majority of suppliers were USA based companies Apart from the six USA based companies, the list included one Canadian, one Scandinavian and one Japanese supplier

Interviewees were not fully informed as to the precise location of manufacturing It was clear though that some of the network cards were manufactured in Ireland At the time the first interviews were conducted, Intel, 3-com, Cabletron and Madge Networks were all manufacturing networking components in Ireland However, according to the interviewees, most of the network cards were imported from the USA or the Far East The network cards of the larger suppliers could come from any of their global manufacturing sites Furthermore, many network component suppliers had already outsourced a large part of their manufacturing activities For example, IBM cards were manufactured in Singapore and China by a Singapore based global CEM [16]

[15] Only Gateway had specifically negotiated that most of its network-card requirements were to be manufactured in 3-Com's Dublin plant

[16] This outsourcing process has continued since the first interviews were conducted For example, in 1999 Madge Networks outsourced its manufacturing and sold its Dublin plant to Celestica (McGrane, 1999) Cabletron was one of the last networking companies to completely outsource manufacturing when it sold its manufacturing plants in the US and Ireland to Flextronics, a USA based CEM (*The Irish Times*, 29-03-00)

Finally, some of the larger computer makers required other networking components such as routers and switches for their networking services arm However, the sourcing of these components fell outside the remit of the manufacturing operations and was therefore not discussed

5 2 11 Graphics, Video and Sound Cards

At the time the interviews were conducted the market for graphics, video and sound add-in cards was extremely volatile The technology involved was changing all the time and computer assemblers regularly changed supplier depending on which supplier was first to market with a new technology Chip suppliers and card suppliers were vertically integrating in an attempt to secure supplies or markets Furthermore, OEM computer makers were seeking to integrate the technology into the motherboard, increasing the demand for graphics and sound chips, but reducing the market for add-in cards

Individual computer makers typically used graphics/video cards from two main suppliers, although, again, suppliers were changing all the time Suppliers included two Canadian, five USA based and one German company Some of these companies were still assembling cards in their own factories Thus, Matrox assembled its own cards in Canada, STB in Mexico, while Elsa had an assembly plant in Germany However the other suppliers had already outsourced card assembly, typically to companies with plants in the Far East

At the time the interviews were conducted, the sound technology for many computer models was already integrated into the motherboard For the models where this was not the case, individual computer makers used one or two suppliers Suppliers mentioned included five USA based companies, two Japanese and one Singaporean company[17] In nearly all cases card assembly was outsourced to CEMs with plants in the Far East The exception was Creative Technologies who still assembled its own cards in Singapore

[17] Although many sound-card suppliers were USA based, the world leader by far was Singapore based Creative Technologies (Kraemer and Dedrick, 1998)

5 2 12 Cables and Interconnect

This category covers a wide range of cables such as power cords, wire harnesses and signal cables, often with connectors or terminators assembled This was a very fragmented business The main players were large MNEs with several manufacturing facilities across the globe, including Ireland and Scotland, although smaller indigenous companies were involved as well

The computer companies in Scotland sourced a large part of their cable requirements from eight USA based, one Taiwanese and one UK based company (Volex) while small amounts of cables were sourced from two Scottish (Fullarton and Clairemont) and two German companies The focal companies located in Ireland sourced a large part of their cable requirements from Keytech, an indigenous manufacturer and turnkey supply-chain-manager of interconnect material, as well as from a Taiwanese, a Japanese , a German and a USA based multinational

It proved very difficult to determine the precise geographical source of the cables and interconnect material Although companies received interconnect material from the local facilities of the MNEs, not all material was necessarily manufactured in these local facilities Secondly, the computer assemblers sourced part of their requirements through local supply-chain-management companies on a turnkey basis and were not always informed as to the precise location of manufacturing

The interviews did reveal that a large part of the cable requirements of the computer companies was manufactured or assembled locally The computer companies in Scotland, used cables manufactured in the Scottish plants of Amphenol, Phoenix, Techdyne, Volex, Fullarton and Clairemont, the Irish plants of Molex, Volex and Methode Electronics and the Volex plant in England Assemblers in Ireland used cables manufactured in the Irish facilities of Keytech, Molex and LD Intercon However, the trend was towards a decrease in local sourcing and a (increasing) majority of cable requirements was imported, mainly from the Far East and, to a lesser extent, from the USA.[18]

The supply lines of cables were often indirect. Thus, seven computer assemblers received the external power cables via supply-chain-managers and on a turnkey basis (i.e. the supply-chain-manager bought and stocked material and subsequently supplied it to the focal companies) – nearly always as part of the country kit (see under kits). Similarly four companies sourced at least part of their internal cable requirements via supply-chain-managers on a turnkey basis. Furthermore, many internal cables were supplied as part of the pre-assembled enclosures by the enclosure suppliers who managed the supply chains of cables on a turnkey basis.

5.2.13 Screws, Fasteners and other 'C-class' Items

The computer companies used a variety of c-class items – from screws, fasteners, buffers and plastic stand-offs to printed labels. Virtually all threaded components, stand-offs, etc. were imported, notably from the USA. Plastic product identification labels and badges were sourced from the USA, as well as from two local manufacturers – Industrial Print in Ireland and Donprint in Scotland (both part of UK based Worldmark Group).

All computer assemblers assigned local specialised hardware supply-chain-managers to manage the supply chain of their hardware requirements, in some cases including cable and interconnect material, on a turnkey basis. In Ireland this market was strongly concentrated with all computer companies using the services of locally based Quality Electronic Fasteners, although two assembler used other locally based companies as well, notably MacB and Irish Moulded Products. The computer assemblers in Scotland each used their own local specialised supplier, *inter alia,* USA based NABS, UK based TR

[18] Since the first interviews were conducted, Volex has shifted some of its power cord manufacturing activities from England to South-East Asia in 1999 (*This Is Lancashire* [online], 18-03-99, www.thisislancashire.co.uk/archive/1999/03/18/NEWS4VQ.html) and Amphenol closed its Scottish cable manufacturing plant in 2001 (Interview Information Officer, Amphenol, February 2001).

Fastenıngs and Geltron Sun used ıts regular supply-chaın-manager, USA based BG Turnkey

5 2 14 Dısplays

Typıcally, the computer assemblers sourced theır monıtors and notebook screens from three to five dıfferent supplıers The vast majorıty of dısplays were supplıed by four Korean, five Japanese and two Taıwanese companıes IBM also offered ınternally desıgned flat-panel monıtors, manufactured by contractors ın South-East Asıa Three computer assemblers receıved a small number of hıgh-spec monıtors from two European companıes The LCD dısplays for portable computers were manufactured by sıx Japanese and two Korean companıes Three of the focal companıes receıved these dısplays wıth the partly ıntegrand portable systems, pre-assembled ın Taıwan, Korea and Japan (see under metal and plastıc parts) IBM receıved part of ıts LCDs from a partly owned company ın the Far East

Although a large part of the dısplays were manufactured ın the home countrıes of the Asıan MNEs ınvolved (notably Japan, Korea and Taıwan), many models were assembled ın subsıdıarıes located ın other countrıes ın the Far East, notably Sıngapore, Malaysıa, Chına and Thaıland Although there were no dısplays manufactured ın Ireland or Scotland, five computer makers receıved monıtors from manufacturıng facılıtıes located ın Wales (Sony and LG Electronıcs) and/or the North of England (Samsung and Tatung) However, these manufacturıng facılıtıes were only responsıble for the final assembly of a mınorıty of all requıred models – the majorıty of models supplıed by these multınatıonal companıes was manufactured ın the Far East Sımılarly, Phılıps supplıed two of the focal companıes wıth monıtors manufactured ın Hungary but also supplıed monıtors manufactured ın Chına, Taıwan and Mexıco Fınally, Nokıa supplıed focal companıes wıth monıtors supplıed ın Fınland and Hungary

5 2 15 Keyboards, Mice and Joysticks

As regards keyboards, companies typically used one or two multinational suppliers The main suppliers included three Japanese and two Taiwanese companies while two USA based companies figured less prominently At one stage, most of the required input devices were manufactured in Ireland by subsidiaries of MNEs such as Alps, Mitsumi, NMB and Keytronics However, in the second half of the 1990s the location of these facilities in Ireland became less and less competitive and all companies ceased the actual manufacture of the devices in Ireland In a period of two years, Keytronics (O'Kane, 1996), Alps (Hogan, 1998) and Mitsumi *(The Irish Independent*, 08-01-98), all laid off substantial numbers of production workers and basically continued as distribution operations, only retaining a limited localisation capability

At the time the first interviews were conducted, virtually all keyboards were manufactured in the Far East, notably South-East Asia or China The key-cap laser printing for the high volume language boards, notably boards for the English speaking market, typically took place in the Far East as well However, lower volume language boards were typically printed in Ireland or Scotland Thus, the computer makers in Ireland had their lower volume boards localised in the local facilities of Keytronics, Alps and Lite-on, while NMB had its boards localised in Ireland by BG Turnkey, a USA based turnkey company Similarly, part of the keyboards used by all but one of the focal companies in Scotland were localised at the local facilities of NMB and/or Chicony, while Alps in Ireland was used on one occasion as well The keyboards used by Sun were localised in a BG Turnkey facility near Sun's distribution centre in Holland

The main supplier of mice was Switzerland based Logitech Ireland had long been the biggest global source of mice until Logitech stopped manufacturing mice in Ireland in the mid-1990s (O'Kane, 1995) At the time the interviews were conducted all mice were manufactured in the Far East, notably in China Similarly, where applicable, the single biggest source of joysticks was Logitech and all joysticks were manufactured in the Far East

The supply lines of mice and, to a lesser extent, keyboards were often indirect Thus, a number of focal companies that had outsourced the kitting of country or accessory boxes received part of their mice and keyboard requirements as part of the kit, typically on a turnkey basis (see under kits)

5 2 16 Printers, Scanners and Digital Cameras

The focal companies sold small amounts of printers, scanners and cameras as options Typically the supply chain of these items fell outside the remit of local manufacturing operations and not all interviewees were fully informed as to the exact geographical origin of these items

Only five of the computer companies in this research actually sold printers In the past, a number of companies offered their own branded printers, but at the time the interviews were conducted, Apple and Digital were the only companies still doing this Three other companies offered well-known Japanese and US brands Most printers were imported from the Far East, the USA, Canada and Spain One focal company received Epson printers manufactured in Telford, England However, the majority of Epson models were manufactured in the Far East, notably Indonesia, and merely repackaged in Telford

At the time the first interviews were conducted the market for scanners and digital cameras was still in its infancy Only four computer makers sold very small amounts of branded scanners supplied by established USA and Europe based companies Interviewees were not informed as to the exact geographical origin but none of the scanners were manufactured in Ireland or the UK Two companies offered digital cameras supplied by Sony and manufactured in the Far East

5 2 17 Speakers and Microphones

Six of the interviewed computer makers were selling speakers and microphones The main suppliers involved four established USA based names and to a lesser extent, a number of smaller Asian companies Nearly all speakers and microphones were manufactured in the Far East, notably China Only Sun used microphones manufactured in England, by Japanese Hossiden Besson The supply chain of microphones was not always direct A number of focal companies that had outsourced the kitting of country or accessory boxes received part of their microphone requirements as part of the kit, typically on a turnkey basis (see under kits)

5 2 18 Docking Stations for Portable Computers

Four computer makers sold small amounts of docking stations as an option In all but one case these stations were sourced as a finished product The stations of two focal companies were manufactured by two Japanese and one Taiwanese company in the Far East Two other focal companies manufactured the stations on-site The components, mainly plastic mouldings, power supply and network card, were sourced from the same suppliers as mentioned under the relevant sections above

5 2 19 Media

Media involved items such as CD-ROMs and printed manuals In most cases these items came together as shrink-wrapped packages In most cases these packages were supplied by five specialised USA based software distribution companies with one or more facilities in Ireland and/or Scotland (Thompson Litho, Sykes, US Print, Modus Media, and Gardener Gibson) A small number of cases involved the local facilities of more general turnkey companies (BG Turnkey and Printech)

However, the local facilities were not involved in actual CD-ROM replication They merely shrink-wrapped the CDs together with documentation for distribution As regards the CDs, the suppliers acted as turnkey supply-chain-managers Interviewees were not always informed as to the actual location of CD manufacturing The interviews did make clear that a substantial part of the CDs was replicated in Ireland or Britain Thus, some of the CDs were replicated in the Irish facilities of Germany based Sonopress and USA based Zomax However, some CDs came from further afield One of the distributors, Modus Media, sourced its CDs from three companies Zomax in Ireland, Nimbus in Wales (both USA based) and Sony in Austria (Interview Fisher, Modus Media, February 2001) US Print replicated its own CDs in the USA (Interview, Meek, US Print, February 2001) Finally, Digital sourced CD-ROMs from its own replication and wrapping facility in Galway, Ireland

Printed matter was either produced by the wrapping companies in-house or subcontracted As regards the Irish market, Modus Media and Printech both operated their own litho-printing facility in Dublin while BG Turnkey had subcontracted the printing to two indigenous printers in Dublin (Colorman and Printech) A large part of the printed material for the Scottish market came from Ireland as well Thus the Scottish wrapping facilities of Modus Media and Printech had some limited digital printing capability for print-on-demand requirements The high-volume litho-printed material supplied to the kitting facilities in Scotland, came from Dublin Thompson Litho and US Print did their own litho-printing on-site

The supply lines of wrapped media were often indirect with six of the focal companies receiving at least some of their media as part of the country kit, typically on a turnkey basis (see under kits)

5 2 20 Kits

Language specific items as well as small accessories were generally packed in a separate box, the 'country kit' or 'accessory kit', to be added to the generic computer systems for shipping to the end-customer The content of these kits varied from company to company and could vary from order to order The kits typically included the media, power cable, the mouse, the keyboard, country specific connectors and, in some cases, even more generic items such as the speakers and the microphone Some companies used different kits for market-specific items and generic items

Five focal companies carried out the kitting activities themselves on-site However, the other focal companies contracted at least some of the kitting activities out to supply-chain-management companies who typically supplied the components on a turnkey basis In Ireland the focal companies used one of the three facilities of USA based BG Turnkey while one focal company also used Walsh Western The focal companies in Scotland used the local facilities of USA based BG Turnkey and Modus Media as well as Brands Electronics, an indigenous turnkey company

Obviously, there was some overlap between kitters and the CD-ROM replicators and printing companies mentioned in the previous section Most companies were diversifying into integrated manufacturing support companies Thus media distribution companies could have a substantial printing and kitting business and printing or CD-ROM replication companies were diversifying into kitting activities [19]

5 2 21 Packaging Material

The main packaging requirements were corrugated boxes, foam and some plastic cover All but two focal companies sourced all their packaging needs from local suppliers The focal companies in Ireland used one or more indigenous suppliers (Smurfit, Ire-Tex/ILP, Fitzpack and Hi-term) Some of the suppliers operated several local facilities The focal companies in Scotland sourced packaging from the local facilities of Smurfit, as well as

[19] For example, at the time the first interviews were conducted, Printech, initially a printing company, was marketing itself strongly as a media kitting and hardware supply-chain-management company and changed its name to SerCom Solutions By 2001, the company carried out printing, as well as kitting and supply-chain-management activities for IBM (Interview O'Grady SerCom Solutions, February 2001) Similarly,

from a range of indigenous suppliers (Macfarlane/ A&W Fullerton, Rexem, SCA, Dewar Brothers, Arkol, Hamilton, KWR, Scotfoam and Foamplus)

*5 2 22 **Sub-assembly and Rework Services***

As indicated above (see under metal and plastic parts), suppliers of enclosures and backpanel boards, often carried out additional assembly activities as well Thus, enclosure manufactures typically integrated brackets, floppy drive, power supply, internal cables, and in some cases, even boards Similarly, two of the board manufacturers in Scotland (Solecton and CTS) assembled their on-site produced boards into enclosures for data storage systems for two of the focal companies

Apart from this, eight turnkey companies were involved in a range of sub-assembly and rework activities[20] In most cases these activities were really part of a broader supply-chain-management/ warehousing role that these companies performed in relation to the part or component involved In these cases the actual customer was a hardware supplier, rather than the focal company

All turnkey companies were located in the same country as the customers they supplied The suppliers involved were all variegated companies, offering a range of supply-chain-management and value added services Thus, as mentioned above, apart from its media and kitting activities, Brands in Scotland was assembling plastic components onto hard discs for Compaq, and assembled flat-pack enclosures for two of Compaq's suppliers located in the USA Similarly, Tech-source an Irish supply-chain-management company carried out minor sub-assembly on portable bases, imported from Singapore, before they were delivered to Apple Simclar, a Scottish turnkey company, was going to carry out assembly work on the high-end severs of Digital Earlier mentioned Clairemont Electronics carried out small amounts of sub-assembly work for Compaq and IBM IBM

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disk replicators such as Sonopress and Nimbus were marketing themselves as general 'turnkey companies' – providing disk replication services as well as printing, packaging and supply-chain-management services also received small amounts of sub-assembly services from Turnkey, another Scottish company. Three companies were involved in limited rework activities. Chip, an indigenous turnkey company, carried out rework on parts for Apple in Ireland. Sonnel, a Scottish turnkey company, was involved in rework on parts for Digital, while BG Turnkey carried out rework in its Scottish facility on parts for Compaq.

5.2.23 Components for Board Assembly Line.

At the time the first interviews took place the local facilities of Intel, Apple, and Sun had just ceased all board assembly activities and only four companies (Digital, IBM, Apricot and Compaq) were still populating printed circuit board for their server models on-site.[21] Although often a small part of the total manufacturing activities, board assembly involved a great number of components and suppliers. One can distinguish four generic component groups: etched bare boards; active components such as microprocessors, core logic chips, memory, controller chips and other semiconductors; passive components, i.e., capacitors and resistors; surface-mount interconnect parts, jumpers and switches. The main components, in terms of value, were the microprocessors, some of the other semiconductors and the etched boards. Most of the other components had an extremely low value.

The etched boards were sourced from a range of companies. Important suppliers included five USA based companies, two Taiwanese, one Austrian, one Hong Kong based and one British company (Exacta Circuits which is part of the UK Forward Group). Some of the USA based suppliers were servicing their customers from plants in the USA. But most suppliers used plants in the Far East, notably China. One supplier manufactured in Austria. USA based Viasystems was the only company that manufactured in England (to

[20] Rework is the removal of a part from, or adding of a part to, an existing product, typically a populated printed circuit board.

[21] Only three of these companies, Digital, IBM and Apricot provided structured information regarding the inputs of the component for board assembly. Limited information was provided by Compaq. Furthermore, in a post-hoc interview, information was obtained on Intel's board assembly activities, that had ceased in the first half of 1998. Data presented in this section is based on information provided by four companies, Digital, IBM, Apricot and Intel.

supply Apricot), but even this facility closed in 2001. Exacta used to supply Digital from a facility in Scotland but this facility had already closed in 1997.

As regards active components, microprocessors and memory have already been discussed in the relevant sections above. Graphic and sound chips were supplied by the same companies that supplied the cards, as well as two other USA based suppliers. Apart from these chips, a great number of other semiconductors was sourced from as many, often specialised, suppliers. The main suppliers mentioned included 13 USA based companies, one Dutch and one German company.

In many cases it proved futile to attempt to establish the actual location of manufacturing. Microprocessors and memory aside, any of semiconductors supplied by the larger suppliers could have been manufactured in any wafer fabrication (Fab) and or integrated circuit packaging[22] plants in the suppliers' global production networks and the actual plants used could change with the life cycle of a particular technology. Furthermore, many suppliers have contracted out part or all of the wafer fabrication and/or packaging activities to sub-contractors. Here too, the actual location of production changes regularly. The information available did show that some of the semiconductors are packaged in the USA. However, many companies operated packaging plants in other places as well, mainly in the Far East and, to a lesser extent, in Europe. Furthermore, most of the packaging subcontractors operated out of the Far East. Almost none of the semiconductors used by the focal companies were packaged in Ireland or Scotland, apart of course from the small amounts of microprocessors and memory mentioned earlier.

As regards the passive components, resistors and capacitors were sourced from an extensive range of global suppliers – nearly all Japan and, to a lesser extent, USA based. Again, it proved difficult to establish the exact location of manufacturing. Although passive components were typically manufactured in-house, most suppliers were large global companies with multiple production facilities in many countries, notably in the Far

[22] Packaging involves the assembly of the casing and interconnections onto the individual semiconductor die.

East, the USA, Mexico and, to a lesser extent, Europe and Israel. According to the interviewees, most passive components used by the focal companies' European operations were manufactured in the Far East, although some passives originated in Europe. The only supplier producing locally was AVX/Kyocera in Northern Ireland, and, according to the interviewees, even in this case many of the part numbers were actually manufactured in other locations.

Other components for board assembly included surface-mount-interconnect material, jumpers, switches, etc. Again, the focal companies involved in board assembly used a range of suppliers. The main suppliers mentioned included four USA based and one Taiwanese company. Nearly all of these parts were manufactured in the Far East and the USA. At the time the interviews were conducted Molex and Amp were the only local suppliers. Molex manufactured a small amount of surface-mount-interconnect material in its Irish facility for one of the focal companies. Amp manufactured material for two of the focal companies in its facility in Scotland, but this plant closed in 1999.

5.2.24 Summary of Location of Suppliers

Clearly, the geographical configuration of the supplier networks differed from company to company. However, great commonalities did exist, especially as regards the regional supply situation. The main 'outlier' was Packard Bell-NEC in Scotland. Mainly due to the recent establishment of the plant, parts and components that other companies typically sourced locally, were still imported by Packard Bell-NEC. However, at the time the interviews were conducted, negotiations with local suppliers were already underway[23]. Apart from this, the main difference between the focal companies concerned the location of the motherboard/backpanel suppliers. The geographical configuration of the production linkages in the microcomputer hardware industry is summarised in Table 5.2

[23] They had already decided to source their volume enclosure models from Fullarton and part of their cable requirements from Simclar, both located in Scotland

Clearly, the vast majority of components and parts were imported from regions outside Ireland and Britain, notably from the Far East and, to a lesser extent, the USA. The only items characterised by significant sourcing in Ireland and/or Scotland were: complete computer systems assembly, enclosures, motherboards/backpanels (mainly Scotland), network cards (Ireland only), low volume keyboards, media, kits, packaging material, and sub-assembly services. Furthermore, England and Wales figured to a small extent in the area of monitors while England played a role in the supply of motherboards as well[24]. However, most of these components were imported from other regions as well. Thus, the majority of motherboards/backpanels[25], network cards, cables, keyboards, monitors, as well as significant parts of the complete computer systems and enclosure supplies, were manufactured in other regions, notably in the Far East and the USA. The only components that were mainly sourced from suppliers in Ireland or Scotland were enclosures, packaging, media, kits and low-volume keyboards.

As regards the regional supply network, a detailed list of the suppliers located in Ireland and Scotland, as well as the rest of Britain, is provided in Appendix D. The location of the regional suppliers of the focal companies in Ireland and Scotland has been graphically depicted in Figures 5.1 and 5.2.[26] The suppliers have been categorised according to the main product that they supply to the focal companies, rather than according to their wider activities[27]. Furthermore, in relation to multi-plant firms, all end-product producing plants involved have been included.

[24] Only one supplier, Celestica, was involved. However, this CEM supplied a large part of the motherboard requirements of Dell and, to a lesser extend, Sun and IBM.

[25] Dell and Sun were the only two companies that sourced the majority of their board requirements from regional suppliers (mainly UK), although a large part of the motherboards used by AST and Intel's system assembly plants came from regional suppliers (Ireland) as well.

[26] Earlier drafts of these maps were presented at the Conference of Irish Geographers (Van Egeraat, 1999) and the Regional Science Association European Congress (Van Egeraat, Turok and Jacobson, 1999). The maps included in this thesis differ from these earlier drafts, partly because of the application of a new categorisation and partly because plants were omitted/added, based on revised information obtained in subsequent interviews with the focal companies. The maps in this thesis are the same as those presented at the annual meeting of the Association of American Geographers 2002 (Van Egeraat, Jacobson, and Phelps, 2002) and the conference Ireland 2020 (Van Egeraat and Jacobson, 2002).

[27] This is an important distinction since many suppliers supplied, or aspired to supply, a wider range of component and/or services. Thus, many of the companies involved in the supply of media and kits and the companies involved in sub-assembly often advertise themselves as 'turnkey companies' or 'manufacturing services companies', with an ability to supply a range of components and to provide a range of services, including full system assembly. Similarly most of the major enclosure suppliers offered turnkey system assembly services on a turnkey basis. However, the actual involvement of most suppliers was uni-

The regional supply network included 109 companies and 125 plants and the majority of plants were supplying two to three focal companies (see Appendix D). However, there was less to this than meets the eye. The actual production activities in many plants were very limited or added limited value to the product – a characteristic captured by open symbols in the maps. Thus, apart from limited digital printing activity, the eleven kitting plants were merely packaging media and other language specific parts into a box.[28] Similarly, the five keyboard localisation plants were merely laser printing (non-current language) keyboards manufactured overseas. Finally, the production activities of the turnkey suppliers involved in rework activities were of a very limited nature.

Ten focal companies provided an estimate of expenditure on locally (Ireland or Scotland) manufactured components as a percentage of total expenditure. Figures were also provided for the share of components sourced in Ireland and Britain together. At the time the interviews were conducted, on average, ten per cent of the parts and components sourced by the focal companies in Ireland were manufactured in Ireland (ranging from seven to 12 per cent). The items manufactured in Britain were good for another four per cent on average (ranging from zero to nine). As regards the focal companies in Scotland, on average seven per cent of the material inputs was manufactured in Scotland (ranging from two to nine per cent).[29] The items manufactured in the rest of Britain and Ireland made up another nine per cent (ranging from three to ten).

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dimensional (see Appendix D). Notable exceptions involved Brands Electronics, Fullarton Computer Industries and BG Turnkey Services.

[28] For this reason, the plants involved in actual media production, that is, manual litho-printing of manuals and CD-ROM reproduction, were included as a separate category.

[29] Packard Bell sourced an extremely low part of its material inputs in Scotland, largely due to the fact that the recently established plant was still in the process of forging local linkages.

Table 5.1. Summary of geographical sources of parts and components and country of origin of suppliers

Material input	Main geographical sources of parts and components	County of origin of suppliers
Complete computer systems	Mainly Local, England and Taiwan; portables mainly Taiwan	Mainly Taiwan; one indigenous company
Enclosures and racks	Mainly Local and Far East for volume models and portables; USA and local for less current models and racks	High volume model: mainly USA and Taiwan, and some indigenous
Motherboards, backpanels and riser cards	For most focal companies: Mainly Far East and, to a lesser extent, USA. For two focal companies: mainly Scotland and England	Mainly USA and, to a lesser extent, Asian.
Microprocessors	Mainly South-East Asia, small amounts from Ireland; USA for proprietary technology	All USA
Memory	Mainly Korea and Japan and small amounts from USA and Europe	Mainly Korea and Japan and, to a lesser extent, USA
Hard disk drives	Far East, notably Singapore	Nearly all USA
Floppy drives; CD-ROM drives; CD-RW drives and DVD drives	Far East	Nearly all Japan
High capacity disc and tape drives	Mainly Far East for lower-end technology; USA, Far East, and Europe for higher-end technology	Mainly USA
Power supply	Low-end: mainly China, Malaysia and Thailand; High-end: USA and, to a lesser extend, Far East, Europe and England	Lower-end: mainly USA and Taiwan High-end: Mainly USA, some Europe and Far East
Heatsinks	Mainly Far East, notably Taiwan; to a lesser extent USA and England	Mainly USA and Taiwan, one UK
Cooling fans	Mainly Far East; to a lesser extent USA; some England and Germany	Mainly Japan and USA
Batteries and AC-adapter (for portables)	Far East	Far East, notably Japan, and USA
Modems and network components	Mainly Far East and USA, although four suppliers were manufacturing in Ireland	Mainly USA; Canada, Japan, Taiwan, UK and Scandinavia all represented with one or two companies
Graphics, video and sound cards	Mainly Far East, notably South-East Asia; Individual sources in USA, Canada, Mexico and Germany	Mainly USA and, to a lesser extent, Canada, Singapore and Japan
Cables and interconnect	Mainly the Far East and, to a lesser extent, Ireland and Scotland.	Mainly USA and to a lesser extent UK and Far East and Ireland
Screws, fasteners and other c-class items	USA and, to a lesser extent, local	Unclear, most likely USA and Indigenous
Displays	Mainly Far East; Wales and England for some models.	Mainly Japan, Korea and Taiwan
Keyboards, mice and joysticks	All Far East, notably China and South-East Asia; printing of low volume key-board models local	Japan, Taiwan, Switzerland and some USA
Printers	Mainly Far East; to a lesser extent USA, Canada, Europe and England	USA and Japan

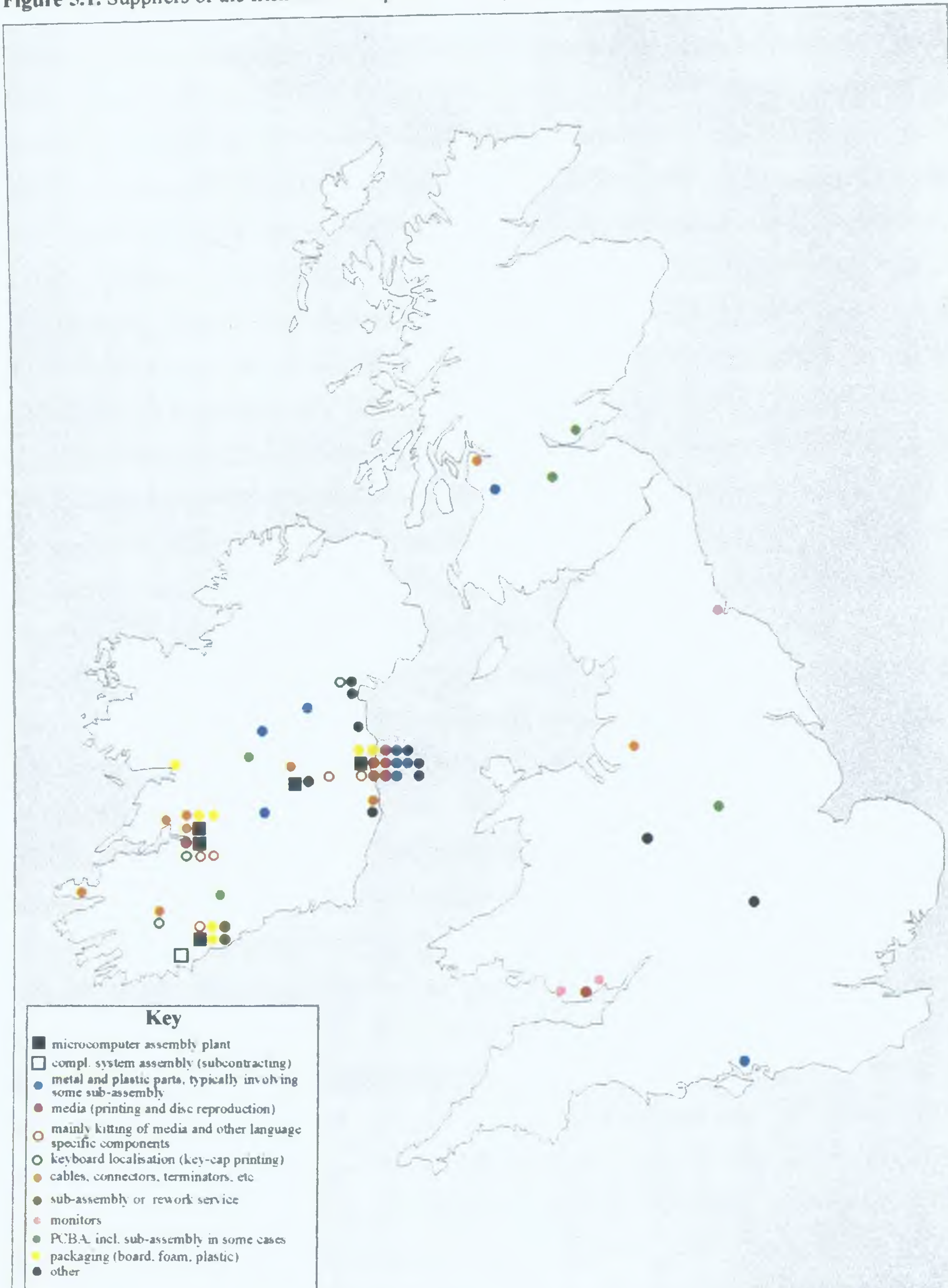
Continues on next page

Table 5.1. Summary of geographical sources of parts and components and country of origin of suppliers (cont.)

Material input	Main geographical sources of parts and components	County of origin of suppliers
Scanners (very small)	Unclear, but not in Ireland or the UK	USA and Europe
Digital cameras (very small)	Far East	Japan
Speakers and microphones	Mainly Far East, notably China	Mainly USA and, to a lesser extent Far East
Docking stations	Far East and on-site	Japan, Taiwan and in-house
Media	Wrapping: local; Printed manuals: mainly Ireland, and to a lesser extent Scotland; CD replication: Ireland, Scotland, Wales, Germany, USA	Wrapping: mainly USA; CD replication: mainly USA and some Germany and Japan; Printed manuals: mainly USA and Ireland
Kits	Local	Mainly USA, some indigenous
Packaging material	Local	Mainly indigenous
Sub-assembly services	All local	Mainly indigenous
Inputs for printed circuit board assembly activity		
Etched boards	Mainly Far East and USA	Mainly USA; individual companies Hong Kong, Taiwan, Austria and UK
Microprocessors and memory	See above	See above
Other semiconductors	Mainly Far East; to a lesser extent, USA and Europe; almost no local	Mainly USA
Capacitors and resistors	Mainly Far East	Mainly Japan and, to a lesser extent, USA
Interconnect, jumpers, switches etc.	Mainly Far East and USA	Mainly USA and some Far East

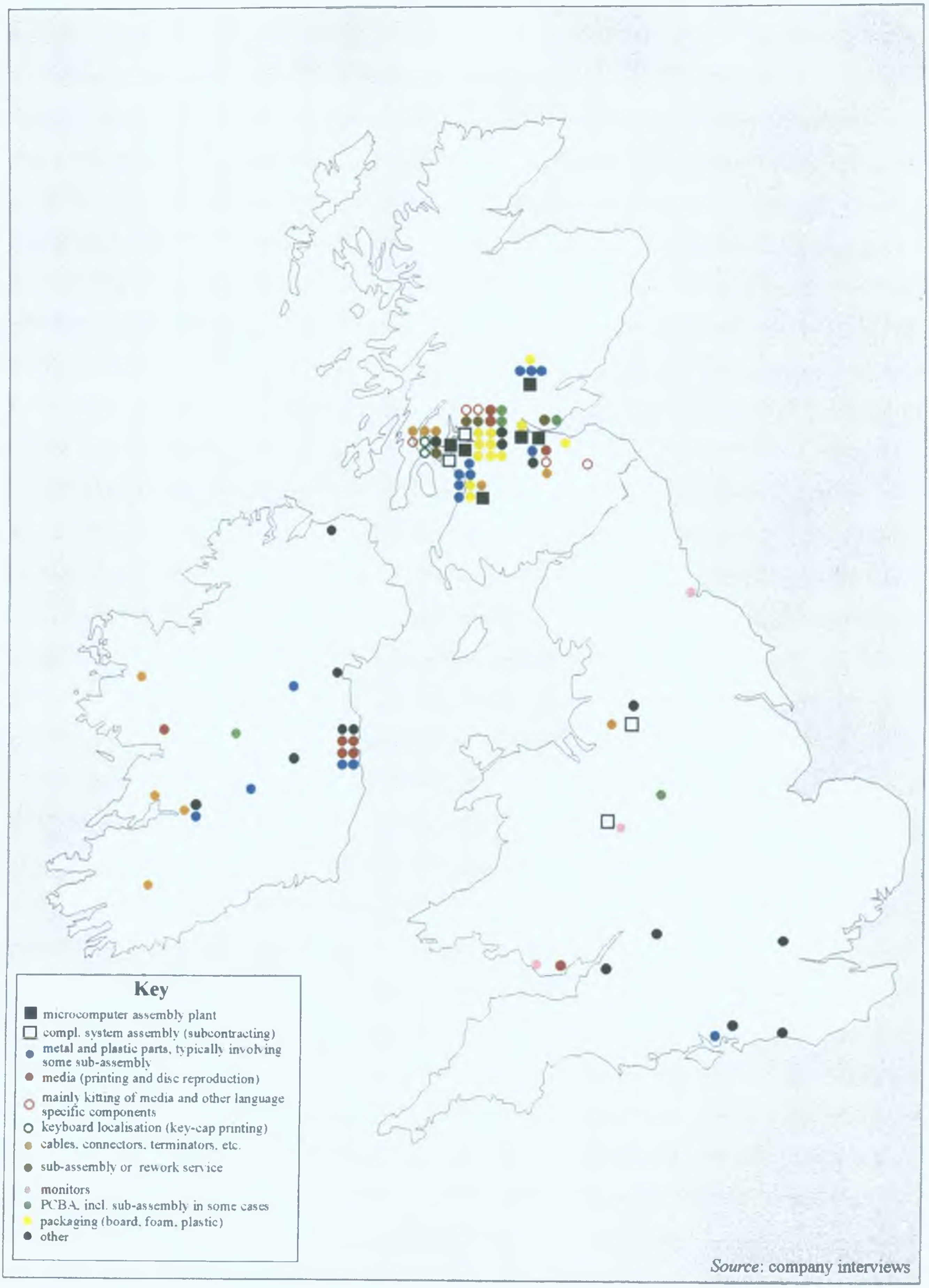
The figures on local sourcing (Ireland or Scotland) presented above are substantially lower than those presented by the industrial development agencies in Ireland and Scotland (see section 4.4). Again, the most likely explanation for this is that the latter figures include items bought from local turnkey supply-chain-managers but manufactured in other regions. The detailed investigation of the supply chains in the microcomputer hardware industry in this dissertation does not support the idea, expressed by some academics (Estall, 1985; Kenney and Florida, 1992; Mair, Florida, and Kenney, 1988), that the adoption of NHVP approaches will significantly increase the proportion of material inputs manufactured in the local economy

Figure 5.1. Suppliers of the Irish microcomputer assembly plants in Ireland and Britain. 1998-99



Source: company interviews

Figure 5.2. Suppliers of the Scottish microcomputer assembly plants in Ireland and Britain. 1998-99



Source: company interviews

The regional supply networks were geographically concentrated in Ireland and Scotland. Only one supplier was located in Northern Ireland and less than 20 plants were diffusely located in England and Wales. The regional suppliers of the focal companies in Ireland were mainly concentrated in Ireland. Thus, virtually all regional suppliers of enclosures, cables, media, packaging, network cards, c-class items, and localised keyboards, as well as the sub-assemblers, were concentrated in Ireland. The exceptions were the suppliers of motherboards, which were spread over Scotland, Ireland and England, and the suppliers of monitors, which were located in England and Wales. Within Ireland, keyboard localisation and kitting facilities, subcontractors and packaging material plants, tended to be located close to their customers. However, for other supplies, including enclosures, the focal companies maintained links with plants located in any of the three main industrial regions (i.e., Dublin, Cork, Limerick/Shannon), as well as with plants located elsewhere in Ireland.

Similarly, the regional suppliers of the focal companies in Scotland were concentrated in Scotland. All regional suppliers of packaging, c-class items, keyboard localisation facilities, kitters and sub-assemblers, as well as the majority of suppliers of cables, enclosures and motherboards/backpanels were concentrated in Scotland. The suppliers of metal and plastic parts appear to be less concentrated, with five suppliers located in Ireland. However, in all but one case, this involved the supply of low volume enclosures or racks or small metal brackets. The majority of actual media manufacturing plants were located in Dublin but the output of these plants formed an input for the kitting plants located in Scotland. Again, the regional monitor suppliers were located in England and Wales. Furthermore, most other higher-end technology suppliers were more spread over the region, located mainly in Ireland (Intel, Quantum and three network card suppliers) and England (*inter alia*, four suppliers of power supply and/or cooling components). Finally, assemblers of complete computer systems were spread over Scotland and England.[30]

[30] However, the two plants involved in the more traditional 'free-issue' subcontracting model, i.e. APW/ Horman Electronics in Ireland and Fullarton in Scotland, were both located very near their customers.

This section outlined the geographical configuration of the microcomputer supply network. The remainder of this chapter will be used to analyse the forces that shaped this geography and to establish the relevance of the various research patterns set out in Chapter 2

5.3 Relevance of Technical Information Exchange and Logistical Efficiency as Drivers for Proximity

The previous section showed that the vast majority of components and parts were imported from regions outside Ireland and Britain. Still, the focal companies did receive some of their material requirements from suppliers located in Ireland or Britain. This section will analyse the extent to which the choice of the regional suppliers was driven by either of the two NHVP-related buyer-supplier proximity drivers as outlined in Chapter 2: efficient technical information exchange and logistical efficiency.

During the second round of interviews, conducted in the second half of 1999, the interviewees were presented with a list of their regional suppliers. First, the question was asked whether the choice for individual local suppliers was influenced by the fact that these suppliers had a regional manufacturing presence. Subsequently, the question was asked to what extent the choice for a particular local supplier had been influenced by one of the two theoretical drivers. Interviewees were asked to score on a scale from one (this driver played no role) to seven (this driver played a very important role). The results are presented in Table 5.2. Each row indicates a component that was sourced regionally by one or more focal companies. In relation to each component, the scores for individual suppliers at ten focal companies have been added and the averages have been presented in two columns. When interpreting the data it is important to remember that in relation to a number of components, notably memory, tapes, cooling fans, heat sinks, printers and microphones, the scores pertain to a very small number of regional suppliers used by a very small number of focal companies.

Table 5.2. Drivers for choosing a supplier with a regional manufacturing presence

Material input	*Average score for logistical efficiency*	*Average score for technical information exchange.*
Packaging material	7	6
Media and kits	7	4
Enclosures and small metal and plastic parts	7	4
Complete computer systems (CEM)	6	4
Printed labels	5	3
Keyboard localisation	5	2
Cooling fans	5	1
Motherboards/backpanels/riser cards	5	3
Cables and interconnect	4	2
Display monitors	4	2
Hard disk drives	3	2
Microprocessors	1	1
Memory	1	1
Modems and network components	1	1
Tapes	1	1
Heat sinks	1	1
Microphone	1	1
Printers	No data	No data

Source: company interviews, 1999.

The table shows that the importance of the two drivers differs from component to component. It is clear that, where proximity was the result of a deliberate choice to deal with a supplier with a local manufacturing presence, logistical efficiency was the principal driver. Thus, as regards logistical efficiency, complete computer systems, enclosures, media/kits and packaging material all received an average score of seven or six, indicating that this driver played a very important role in the decision to choose a supplier with a regional manufacturing presence. Motherboards/backpanels, cooling fans, cables and interconnect, printed labels and localised keyboards received an average score of five, indicating that logistical efficiency played a relatively important role here as well.

In contrast, efficient technical information exchange proved an important driver only in relation to regional suppliers of packaging material. Complete computer systems, enclosures and media kits all received an average score of four, while motherboards/backpanels and printed labels received an average score of three, indicating that the driver played only a modest role. In all other cases, the driver played no role of significance.

In relation to the regional suppliers of microprocessors, memory, hard disk drives, tapes, heat sinks, modems/ network components and microphones, neither driver appears to have played a role of significance. In these cases the link with particular regional suppliers was 'coincidental', i.e. not the result of a deliberate choice for buyer-supplier proximity. The location of these suppliers, often involved in the manufacture of technology-rich components, is more likely driven by the suppliers' desire to take advantage of the regional production climate.

Focussing on technical information exchange, the lack of substantial regionally specific product development functions meant that, in relation to most components, European operations had a very limited involvement in technological co-ordination and information exchange with their suppliers. As discussed in Chapter 4, in relation to most components, the involvement of European operations in technological co-ordination with suppliers mainly concerned ongoing day-to-day operational issues such as failure analysis and the discussion of general quality issues. This exchange of technical information presented a very weak driver for supplier co-location. The quality engineers of the focal plants were in regular, in some cases daily, face-to-face communication with the main suppliers. However, generally, the exchange could be, and was, handled by local supplier representatives such as account managers, sales engineers or field-application engineers and did not necessarily require contact with the engineers employed at the suppliers' production and design facilities. It was only in the case of major problems that the suppliers' production or design engineers would become involved in the communication. However, this relatively infrequent contact presented no driver for the co-location of fully integrated supplier facilities. Similarly the more formal supplier review meetings, that involved suppliers' production or design engineers, took place on a half-yearly or yearly basis and presented no driver for co-location.

The above mentioned representatives were not only the first port-of-call for day-to-day quality issues but would interact on sales/purchasing planning, logistics and training issues as well. In fact, interviewees found it difficult to distinguish between the various roles, and the scores in Table 5.2 for technical information exchange, in relation to keyboards, cooling fans, motherboards/backpanels, cables/interconnect, monitors, hard disk drives and complete systems, for a large part pertain to demand-level communications with the local account managers.

As discussed in Chapter 4, in relation to some components such as enclosures and motherboards/backpanels, engineers of the European operations played a role in the ramping-up of suppliers' production facilities. Production engineers of the focal companies could be involved in the organisation of the introduction of an existing tool to a regional supplier and in the qualification of the suppliers' production processes. The communication involved face-to-face meetings at the suppliers' production facilities. However, engineering change orders would take place twice a year at most and the non-intensive information exchange involved posed only a weak driver for buyer-supplier proximity. Furthermore, as discussed, the meetings with the supplier engineers often included engineers from corporate production/design facilities located in the USA. Thus, any communication efficiency gain related to the location of suppliers relative to the European operations could be partly off-set by an efficiency loss due to the distance of the supplier to the focal companies' corporate production/design facilities.

As discussed in Chapter 4, European operations played a more substantial role in relation to some less-strategic components. Thus, the technological co-ordination and information exchange in relation to packaging, media/kits, certain cables and printed labels was typically handled entirely by the European operations. However, in most cases the technical information exchange was of a non-intensive nature posing a weak driver for buyer-supplier proximity. The European operations have very regular face-to-face contact with the local suppliers of media and kits but most of the communication could be handled by an account manager of the supplier and would concern mainly demand level issues. The exceptions were packaging material and, in a small number of cases, cables. Packaging and some of the cables are changed or modified on a very regular basis and engineers of European operations had very frequent face-to-face meetings with design/production engineers of local suppliers, discussing, *inter alia*, design, tooling and qualification issues. This information exchange did represent a relatively important driver for buyer-supplier proximity.[31]

Thus, European operations had only a limited role in technological co-ordination with suppliers and the non-intensive information exchange involved presented only a weak driver for supplier co-location. However, other information gathered during the interviews[32] suggests that even if the European operations had played a bigger role in the corporate process of technological co-ordination with suppliers, this would probably not have resulted in supplier co-location anyway.

As discussed in Chapter 4, the design of many components, notably enclosures and motherboards, but also microprocessors, displays and hard disk drives still involved a substantial amount of technological co-ordination between the corporate design facilities and the suppliers. This co-ordination involved a substantial exchange of technical information. However, even at the corporate design/production facilities, efficiency in the exchange of technical information did not pose a strong driver for supplier co-location. The interviews showed two things. First, much of the technical information could be exchanged using non-face-to-face modes of communication, such as electronic mail or tele-conferencing. In relation to this IBM's director of development mentioned:

> It [proximity of suppliers] is useful but not essential. Most of the stuff is transmitted electronically, the drawings, the requirements, the specifications. ... The engineers will visit the supplier only for major process checkpoints, like at the end of the design phase. ... Again, I think geography, is becoming less and less of an issue. It is much more down to the ability to interchange – how good is the company working electronically and how fast are they responding. ... [As to the suppliers with local facilities] our engineers will meet them regularly. Everyday we send them new drawings, new information. They are looking at our tooling development – very close face-to-face information and telephone type communication. The local is interesting, but equally we do business with the Far East, and

[31] This kind of frequent information exchange pertains to a limited number of specialised internal cables only. The importance of the driver in these limited number of cases has found no expression in the average figures on technical information exchange in Table 5.2.

we are also developing products in the Far East and we talk to them daily on conference calls. But we would not meet them face-to-face regularly. So there is a benefit to have them local, but that does not mean that we will only source locally. (Interview Higgy, IBM, July 1999).

Secondly, in those cases where face-to-face communication with engineers of the suppliers' design/production facilities was required, this could be efficiently organised through frequent long-distance travel by engineers of both partners or through the short-term out-stationing of design engineers, either at the facilities of the customer or the supplier – it did not require the co-location of integrated supplier operations. Thus, during the development phase, the focal companies would receive frequent visits from engineers of the suppliers' design/manufacturing facilities or, in some cases, have them stationed at the design facilities for a number of weeks. The latter would certainly be the case with the more strategic suppliers, e.g. suppliers of microprocessors. Alternatively, the focal companies assigned design staff to work for a period at the design facilities of suppliers. Furthermore, some of the technical information exchange could be handled by the above-mentioned sales engineers or a small local general support office. "A lot of suppliers, regardless of where they are situated, have Digital accounts people, who are engineering type sales people, situated in the Massachusetts area, purely to focus on Digital R&D" (Interview Cairns, Digital, July 1999).

The explanation for the limited amount of co-location between corporate design facilities and suppliers is probably two-fold. First, leaning on the ideas and findings of Arita and McCann (2000) (see section 2.4.3), most of the partnerships in the microcomputer industry fall in the category 'manufacturing'. The technical information exchange involved in these 'lower-order alliances' is of a relatively low intensity, i.e. the detail and sensitivity of the technical information exchanged is relatively low. Therefore, technological co-ordination requires low levels of face-to-face contact. Secondly, part of the explanation might lie in the fact that the focal companies and most of their suppliers are all large global organisations. Arita and McCann found that intensive formal technical

[32] The interviews included questions regarding the mode and intensity of technical information exchange between corporate design facilities and the suppliers. Furthermore, similar information was obtained in

information exchange posed a driver for proximity – although, even then, only on the scale of one day's return journey by air. However, their study involved *small* US semiconductor firms only. It is likely that technical information exchange, even the more intensive exchanges, are a less spatially restrictive issue for large multinational organisations.

To summarise, in contrast to the suggestions of Reid (1995) and Schoenberger (1997), efficiency in technical information exchange was a relatively insignificant driver for buyer-supplier proximity. This can be partly explained by the fact that the global business models of the focal companies did not require substantial regionally specific product development and the European operations did therefore not incorporate substantial local-for-local R&D groups. In relation to most components, the technical information exchange between the engineers of the European operations and the suppliers was relatively unintensive and a locally based representative of the suppliers could handle most communication.

Even if European operations had played a bigger role in the corporate process of technological co-ordination with suppliers, this would not have resulted in supplier co-location anyway. Even at the corporate R&D facilities, efficiency in technical information did not pose a strong driver for buyer-supplier proximity. A large part of the technical information exchange was unintensive and did not require face-to-face contact and in those cases where face-to-face communication was required, it was relatively easy to organise the exchange, in an efficient way, with suppliers located further afield. Furthermore, part of the explanation might lie in the fact that all focal companies and most of their suppliers were part of large global organisations. Large MNEs are more used to exchanging detailed and complex information on a global basis.

Where proximity was the result of a deliberate choice to deal with a supplier with a local manufacturing presence, logistical efficiency was the principal driver. However, in relation to a substantial number of regionally sourced components the co-location was

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relation to the on-site system development operations of IBM and Digital in Scotland.

coincidental – i.e., neither driver played a role of significance in the focal companies' decision to use a regional source. Furthermore, as outlined in section 5.2, the vast majority of components were imported from other continents and even some of the components characterised by significant regional sourcing were sourced from other continents as well.

The data presented thus far clearly provide very limited support for research patterns 1a and 1b as outlined in Chapter 2. The remainder of the chapter investigates whether the geographical configuration of the production networks matches research pattern 2a or 2b, i.e. whether the limited local linkage formation came about in the context of an optimal inbound logistics system, taking full account of the modern comprehensive logistics management principles or in the context of a sub-optimal inbound logistics system. Most of the answer will be provided in section 5.5 where data are presented on inventory levels, shipment frequencies and modes of transport. However, the analysis of shipment frequencies and inventory levels requires an insight into the way focal companies had structured their inbound logistics pipelines – the rise of 'hubbing', a recent development which in itself merits extra attention.

5.4 Inbound Pipeline Strategies and Structures

The fact that the vast majority of components and parts were imported from other continents meant that the inbound pipeline had to involve certain inbound inventory levels, if only to buffer against extended transit lead times. However, as was briefly outlined in section 2.4.4, the location of these inventories and the arrangements as regards ownership of the material can take different forms. This section will deal with the innovative way the focal companies in Ireland and Scotland had structured their inbound logistics pipelines. The first section describes the general trend in the industry – the rise of 'hubbing'. A detailed description of the specific strategies and arrangements of individual focal companies is provided in Appendix E. The second section will focus on the advantages of the hubbing system.

5.4.1 The Rise of Hubbing

Until the mid-1990s, the focal companies had a mix of inbound logistical arrangements. A small part of the inputs was already manufactured and supplied on an almost true JIT basis, involving minimal buffer inventories[33]. However, the supply chain of most components still involved larger buffer stocks, in most cases stored in customers' warehouses as customer-owned inventory. In most cases these components were supplied on the basis of a push-model, with vendors reacting to relatively inflexible purchase orders, detailing a fixed amount of product and a fixed delivery date on which customers had to accept the material. Supplies could either come direct from the suppliers' manufacturing facilities or be delivered via the suppliers' regional warehouses.

Since the mid-1990s, the strategy of nearly all focal companies had been shifting towards a 'hubbing' system. In a hubbing system, suppliers that are not able to supply their customers directly from their manufacturing facilities within a certain lead-time are requested to hold an agreed minimum amount of inventory at a location near to their customers – the 'hub'. On a very frequent basis, the customers pull from these hubs, either their exact material requirements (pull-to-schedule) or the amount necessary to replenish minimal on-site buffers (*kan-ban*). The suppliers have the responsibility for maintaining sufficient inventories in the hubs and hold title to these inventories. Suppliers produce and deliver on the basis of very flexible purchase orders, often 'blanket purchase orders'[34]. In many cases customers are not contractually obliged to take the material in the hub and they will only own the material from the moment they pull it from the hubs.

The hubbing system strongly reduced the amount of inbound inventory on the books of the focal companies. It is the hubbing system that partly explains the discrepancy between the use of overseas component sources and the high inventory turns published by some of the focal companies (Casey, 1997; Oram, 1997). The level of inventories on

[33] Apple had implemented true JIT supply systems for selected components as early as 1983 (*International Business Week*, 14-05-84).

[34] A blanket purchase order is no more than a commitment of the customer to purchase a certain amount of material over a certain period of time – more and more the entire life-cycle of a particular model.

the books of the customers depended on the frequency of supplies and, thus, the distance between the focal companies and the hubs or the direct suppliers. Delivery lead-time requirements varied from 24 hours to as low as one hour and some focal companies had organised hubbing facilities on-site. The trend was in the direction of shorter and shorter lead times which allowed companies to pull materials multiple times a day, leading to extremely low inventory levels on the books of the suppliers.

The hubbing system involved warehouses owned by the supplier, the customer, or by a third party. Some of the focal companies pulled material from a multitude of hubs, individually organised by the various suppliers, i.e. 'vendor hubs'. However, there was an increasing trend to consolidate the hubbed inventories into one or two super-hubs. This significantly improved the visibility of the hubbed inventories and the inbound pipeline in general and it reduced the complexity of the pull system. Some companies managed their own super hub. However, in most cases these super-hubs were managed by third-party-logistics (3pl) providers that offered integrated logistics services from facilities located in close proximity to the focal companies (see Figure 5.3). These '3pl hubs' could serve several focal companies.[35]

[35] The term 'hubbing' carries different meanings in the industry. Most companies used the term for both 3pl hubs and vendor hubs. Some companies reserved the term for 3pl hubs only. Other companies referred to all hubbing as 'vendor-hubbing'. In this dissertation, a distinction will be made between 3pl hubs and vendor hubs. 3pl hubs are the super hubs managed by third party logistics providers while the vendor hubs are the hubs chosen and arranged by the individual vendors. However, the distinction is not watertight: some vendors made their own hubbing arrangements with a third-party-logistics provider that had no explicit partnership with the particular focal company.

Figure 5.3. Location of main third party logistics hubs in Ireland and Scotland - 1998

Source: company interviews

The focal companies still used a range of other pipeline structures, including true JIT. But most structures had one thing in common with the hubbing system: they involved locally stored inventories on the books of the suppliers. Thus, focal companies were making increasing use of turnkey supply-chain-managers. In contrast to hubbing, a turnkey supply-chain-manager not only organises the logistics of components but actually buys and holds title to components until they are delivered to the assembly plants, i.e. they supply on a turnkey basis. From an inbound logistics point of view, there was not much difference between receiving supplies from a local hub or from a turnkey supply-chain-manager. In both cases the customer pulled on a very frequent basis from agreed buffers owned by the supplier/supply-chain-manager located in close proximity.

Although some local suppliers were genuinely producing on a true JIT basis, in many cases local suppliers were requested to hold (at their own premises) minimum buffers of finished goods at levels similar to those requested from suppliers delivering through the hubs. Customers did not have to take the material and did not own it until the moment they pulled it from the local suppliers. Again, in those cases there was not that much difference between a hub and a local supplier – the focal companies basically pulled from agreed buffers owned by the supplier.

Finally, a very small number of items at a small number of focal companies were still supplied on a more traditional basis, involving specific purchase orders. Once the orders were placed customers had to take delivery and, in principle, there was no guarantee that material would be available when ordered. However, typically the suppliers involved would stock inventories at regional warehouses so that customer's needed to hold very little inventories. Although, in principle, there were no agreed inventory levels, in practice, focal companies pulled from inventories owned by the supplier.

5.4.2 Advantages of Hubbing

The use of hubs brings great apparent advantages for the customer companies. It greatly reduces the average inventories on the customers' books, particularly in an environment of BTO strategies, short order lead times and unpredictable demand (see Chapter 4). Therefore, for the customer, it reduces the interest costs of holding inventories, the quantity costs, the risk of obsolescence and the costs related to owning and managing warehouses.

In relation to the research questions of this dissertation, it is important to look at the meaning of hubbing for the supply chain as a whole. The hubbing system does involve inbound inventories owned by the suppliers. As discussed in section 2.4.4, some have interpreted the hubbing system as a pseudo JIT system that holds little benefit for the supply chain as a whole since the costs of inventory remain in the system (Lamming, 1993). Suppliers are allegedly 'forced to eat inventories' (Morris, Munday, and Wilkinson, 1993; Roper, Prabhu, and Van Zwanenberg, 1997) and the burden of inventory is therefore simply transferred from the customers to the suppliers.

However, the use of hubs, in itself, does not necessarily mean that the supply system is sub-optimal. The actual ownership and location of the inbound inventories has no relevance from a supply-chain-efficiency point of view. The fact that the supply system diverges from the prototypical true JIT picture does not mean that the comprehensive logistics management principles are not appreciated. In order to determine whether the storage of inventories in hubs involves an optimal or a sub-optimal supply system one requires data on the actual size of the inventories, the shipment frequencies and the mode of transport. These data will be presented in section 5.5.2. However, additional information regarding the detail of the hubbing arrangements/contracts can already cast some light on the issue and will be presented here.

As regards the idea of suppliers being forced to eat inventories, unsolicited statements by a number of interviewees suggest that supplier power did have some influence on the pipeline structure, i.e. on the question whether components are hubbed or not: "Although it is a partner, Intel will not hub. It is just the way Intel are, strong, very big. Dell asked them to hub, but they are a very difficult company to deal with" (Interview Walsh, Dell, October 1999). "Off course, Intel won't hub and a few others with technical power"

(Interview Tyldsley, Digital, February 1999).[36] This might mean that suppliers that lacked the necessary power were forced to carry the burden of inventories.

On the other hand, suppliers were compensated for hubbing. Both the level of the inventories and the charges for the service were negotiated and, typically, focal companies were paying more than the standard price for hubbed components[37]:

> Yes we pay for [hubbing]. ... It is like amortised over the costs of the components we pay. It is a couple of cents a part that we pay for this facility, to gain my turns, to gain my low inventory holdings ... [Interviewer: but in principle it is a zero-sum game for the system?] Overall, yes ... the costs of the inventory ... ultimately I pay for it, absolutely (Interview Flynn, Gateway, March 2000).

Furthermore, hubbing contracts could involve different liability clauses which meant that the risk of obsolescence was not always entirely transferred to the supplier. Thus although in case of many components the focal companies were not liable to take the inventories in the hub at any stage, in other cases, particularly in cases of customised components, focal companies had to take the material in the pipeline after a certain period. Anyway, the risk of obsolescence of hubbed materials was generally kept to a minimum. As discussed in Chapter 4, the partners were intensively sharing information regarding inventory data and demand forecasts which, as will be discussed in the next section, allowed them to tightly manage the inventories in the hubs. The issue of obsolescence generally only arrived if a component was prematurely reaching end-of life. However, even in those cases, flexible marketing would make obsolescence a relative concept:

> If the supplier is located in South-East Asia ... and if I know that there is two plus six weeks worth of inventory on the way to me, our new product introduction will not happen until that is drained ... [We] are always going to use it up. ... Our business model allows us to drive

[36] On the other hand, in 2001 even Intel planned to start hubbing its microprocessors (Interview Darragh, Compaq, April 2001).
[37] Only one interviewee, at IBM, suggested that after negotiation he was basically not paying for the hubbing service.

whatever demand we want, that is the beauty of the thing (*Interview Flynn, Gateway, March 2000).*

Even if the focal companies were not contractually liable to take the product in the pipeline, they would not simply leave suppliers with the inventories. Companies would generally get into end-of-life negotiations and work closely with the supplier to try and bring the inventories down.

So if suppliers are compensated for maintaining inventories in the hubs and the focal companies have to bear the cost of inventories anyway, the question arises: what drives the rise of hubbing? The answer can be found in several other advantages of hubbing. First, a hubbing system, as opposed to a system where each individual focal company carries its own inventories, provides economies of scale in the management of industry standard inventories and allows total inventories to be reduced since inventories in the hubs are being switched between various focal companies. "[Gateway's] buyers get calls regularly where they [the 3pl provider] say, 'IBM has been on to us and would you mind if we took two days worth of inventory and give it to somebody else'. And I say 'that is fine'. Because it works both ways" (Interview Flynn, Gateway, September 1999). This practice can be related to the concept of 'agile manufacturing' (Jackson, 1998). Agile manufacturing is the stitching of lean enterprises into informal alliances. If one participant has a surge in demand, it can exploit any slack remaining in the system as a whole. It can be seen as the answer to the inflexibility of lean production, which can not deal with quick surges in demand. In a similar way hubbing can be interpreted as 'agile logistics'.

Secondly, most focal companies were extremely focussed on short-term performance indicators, such as return on investment, and hubbing allowed them to improve some of these indicators. As one interviewee put it: "Gateway is a public company ... the first thing a Street analyst will look for is our inventory and our turns. Obviously this is a huge opportunity" (Interview Flynn, Gateway, 1999). Thirdly, where the main hubs are located off-site, hubbing can ease space constraints for value added activities on site.

The use of 3pl hubs creates additional advantages over the use of vendor hubs. Both customers and suppliers can tap into the full set of integrated services offered by the 3pl providers. The bigger 3pl providers have the capability to efficiently organise the inbound supply chain 'from birth-to-death', stationing staff on-site at the suppliers' overseas facilities, arranging customs and duty requirements, hubbing the materials locally and delivering the materials to the customers' plants on a JIT-basis. The bigger 3pl providers have developed core technologies and competencies in the area of logistics and supply-chain-management that customers can benefit from. Thus companies like Irish Express Cargo (IEC) and Walsh Western have developed or acquired sophisticated EDI, satellite tracking, radio-frequency scanning and automated customs handling systems that link airlines shipping lines and world-wide partners (Aherne, 1999; Casey, 1998; Dunne, 1998; Lyons, 1998). These systems provide a high degree of inbound pipeline visibility. These capabilities and competencies are not always present at the logistics departments of the individual customers or suppliers. Finally, the use of 3pl hubs provides a ready-made warehousing solution for smaller suppliers that do not have the resources to arrange a local warehouse of their own.

5.5 Optimal or Sub-optimal Inbound Logistics Solutions

This section investigates whether the limited local linkage formation and the use of inbound buffers came about in the context of an optimal or a sub-optimal inbound logistics system. The first sub-section present the definitions of the key logistics data used in the analysis. Using these data along with additional qualitative data, the next two sub-sections show how tightly the inbound inventories were managed and how component characteristics and contextual conditions affected logistics management and the geography of the linkages.

All data and information presented in this section pertain to the situation during the time the first interviews were conducted (second half 1998–first quarter 1999). The data were obtained during the first, second and third round of interviews, although most data were gathered in the second and third round of interviews, conducted in the second half of

1999 and the second quarter of 2001. Three of the focal companies were unable to co-operate in the third round of interviews.[38] Therefore, regarding these three companies, few key logistics data were obtained, although some information was available from the earlier rounds of interviews.

5.5.1 Key Inbound Logistics Data Collected

The focal companies provided data on inbound inventory levels, shipment frequencies and modes of transport pertaining to individual component pipelines.[39] The responses of the individual focal companies have been listed in Appendix F. This section provides more precise definitions of the data provided. The interpretation will follow in the next section.

As regards the inbound inventory levels, all focal companies worked with target buffers which meant that they tried to maintain a certain level of inbound inventories. The target levels pertained to the planned or preferred circumstances. Actual inventory levels typically fluctuated around this target level. Actual inventory levels of certain components could be lower on a more routine basis due to constrained supply. During the time the first interviews were conducted, 1998 and 1999, the microcomputer industry was growing at a rapid rate and from time to time focal companies were confronted with constrained supply for certain components. Similarly, availability could be constrained in case of new innovations where suppliers had not yet put a mature manufacturing process in place.

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[38] By the time of the third round of interviews, Packard Bell had undergone restructuring and new management withdrew their co-operation. Intel and AST were no longer manufacturing computer systems in Ireland and contact with the interviewees that co-operated in the first and second phase was lost. The Digital plant had been fully integrated into the Compaq organisation and the Apricot plant had closed. However, in relation to the latter two companies, contact with two of the interviewees that co-operated in the first and second round of interviews had been maintained and both interviewees co-operated in the third round of interviews.

[39] The focal companies were able to provide a great amount of detailed logistics data. However, with respect to a minority of component categories, e.g. printed labels, screws and fasteners, most focal companies were not strongly involved in the organisation of the inbound logistics pipeline. In those few cases, the information on target inventory levels, shipment frequencies and mode of transport was based on interviewees' informed assumptions.

From the description of the pipeline strategies and structures in section 5.4 it is clear that inbound buffers of the focal companies included more than the inventories stored at the focal companies. Indeed, in most cases the largest part of the buffers was stored at the hubs or at the suppliers' local or regional manufacturing facilities. In some cases, the buffers were split between the hubs/ regional manufacturing facilities and the focal companies' warehouses. The data on target buffer levels in Table F.1 represent buffers kept at hubs, suppliers' local/regional manufacturing facilities, warehouses of the focal companies, turnkey supply-chain-managers or at a combination of these facilities. The data do not include the (small) inventories kept at the plants of the focal companies in the context of hubbing or true JIT supply. As discussed in section 5.4.1, focal companies pulled material from the hubs into their manufacturing plants on a very frequent basis – typically multiple times a day. The system still required certain buffers at the manufacturing facilities of the focal companies – the level depending on the frequency of supply. In most cases the size of these on-site buffers was minimal and has therefore not been included in the figures on target buffer levels. Only Apricot, due to the lower volumes of inputs required and greater distance of the hubs, pulled on a less frequent basis, leading to on-site inbound inventory levels of three to four days.

As regards shipment frequency, the ultimate aim was to establish the fluctuations of the buffer inventories. Therefore, in most cases companies were asked to provide data on the frequency of shipment from the location of component manufacturing to the location of the main buffers (either at the local hubs or the warehouses of the focal companies). A problem arose where the main buffers were positioned at the suppliers' manufacturing facilities, as was often the case with pipelines of inputs manufactured in Ireland or the UK. Here, the concept of target shipment frequency from the location of manufacturing to the location of the main buffer was not relevant since the buffers were fed directly from the manufacturing lines. Where this was the case, Table F.2 does not list figures for the frequency of shipment into the main buffers. However, a figure is provided between brackets, representing the frequency of shipment from the suppliers' facilities to the focal companies.

Focal companies were asked for the target rather than the actual shipment frequencies. The target shipment frequencies pertain to ideal situations of relatively stable production schedules and unconstrained supply. It was not uncommon for the focal companies to be confronted with large non-forecasted spikes in demand and constrained supply. In these situations the focal companies could be forced to fly in material and increase the actual frequency of shipments. However, these situations were not the norm. Strategic decisions – notably the choice of suppliers – were made on the basis of what was expected to be 'normal' practice. Hence, target shipment frequencies were more important in the context of this thesis.

In order to be able to combine the data on target shipment frequencies with the data on target inventory levels, in Table F.2 the shipment frequencies have been expressed in number of working days between shipments. Thus, weekly shipments are indicated as '5' (working days between shipments) and bi-weekly shipments are indicated as '10' (working days between shipments), and so forth. Interviewees regularly used less precise statements. In relation to this, the answer 'a couple of shipments a week', has been coded as '3' (days between shipments). 'Three shipments a week' has been coded as '2' (days between shipment).

Finally, responding focal companies were asked to indicate the preferred mode of transport pertaining to the various material inputs, i.e. truck combined with ferry, ship (ocean) or plane. In effect, the question was only relevant in relation to items imported from other continents. Items manufactured in Europe, the UK and Ireland were invariably transported by truck. Again, the responses listed in Table F.3, pertain to ideal situations of relatively stable production schedules and unconstrained supply. In face of extreme non-forecasted spikes in demand and constrained supply companies often expedited shipments which could involve the use of a different, faster, mode of transport. Although in relation to some components the preferred mode of transport differed between companies, in most cases it was possible to identify a typical preferred mode of transport. These are listed in Table F.3 as well.

To establish how tightly the focal companies managed their inbound logistics, the next section discusses the key logistics data along with additional qualitative data obtained during the interviews.

5.5.2 Were the Inbound Inventories Tightly Managed?

The focal companies imported the vast majority of components and parts from regions outside Ireland and Britain, notably from the Far East and the pipelines of most components involved inbound inventories, often hubbed in local warehouses. However, this section will show that the inbound pipelines were not managed on a sub-optimal basis.

The costs of holding inventories were well appreciated in all focal companies as can be illustrated by the following two extracts (additional support for this point has been provided by Nolan, 1997):

> If the material is extremely valuable the supplier could have millions of dollars in just one hub. If you multiply the number of hubs by the dollars in each hub, the cost of financing this inventory is prohibitive. In this instance the suppliers would negotiate a smaller buffer stock with frequent replenishment. ... In general the higher cost items (processors, motherboards) would be the parts that change from model to model. The life expectancy of our products has shrunk down to as little as three to six months. The last thing we would want is to go end-of-life with millions of dollars worth of parts in our hub at our liability. ... Most of our product we tend to air-freight ... With a short life cycle, which we have with most of our product we tend to use air-freight ... because we don't want to end up with a lot of excess and obsolete [material] before the end-of-life (Interview Barry, Apple, Dec. 2001).

> If you look at our financial performance over recent years we will typically have increased our inventory turns from the order of 12 to 14–16. And we believe speed is an absolutely essential requirement to get your inventory turns up. ... The cost of inventory is very expensive. ... The other thing is our product life cycles ... it does not lend itself for product being on the sea for six weeks or something (Interview Steven, Sun, May 2001).

This is reflected in the way companies managed their inbound inventories. The following quote illustrates the great level of control focal companies kept over the inbound inventories and pipelines:

> I give them [the suppliers] my MRP every week for that product and I expect them to manage the chain between them and the hub, I expect them to turn it up, down, slow it fasten it and manage it so that I always have 10 days in the hub. ... We run queries here every day by part number which sends out an exception report which shows me what suppliers have less than 10 days. And the buyers call them. And it also shows us what we have too much of. And [we] than proactively take actions twice a week. ... All the vendors are on-line to Irish Express Cargo [3pl hub]. All the vendors have the same kind of contact. That is a criterion that Gateway gives ... It is our way of making international suppliers local suppliers (Interview Flynn, Sept. 1999).

The inbound inventories were tightly managed. The key logistics data reveal a picture of modest target buffer levels and high shipment frequencies. As will be discussed below, to some extent the target buffer levels for individual component pipelines varied, depending on a number of interrelated issues, notably the characteristics of the components and the location of manufacturing. However, all companies worked with a generic figure for target inbound inventory, that applied to most parts and components. Thus, Dell, Gateway, Apple, IBM, Compaq, Digital and Packard Bell all worked towards a ten day[40] buffer for most of their material inputs.[41] Intel and AST worked with target buffer levels as well, however, information regarding the size of the target levels was not obtained.

The two 'outliers' were Sun and Apricot. Sun managed its inventories even more tightly than the other focal companies. Thus Sun worked towards a five day generic buffer level and, where other companies received components on a weekly or bi-weekly basis, in

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[40] Most companies expressed the inventory levels in terms of working days of forecasted demand. In most cases five days stood for one week of production and ten days stood for two weeks of production.

[41] IBM worked with a generic target of ten days for hubbed inventories and five days for non-hubbed inventories but, as discussed in Appendix E, nearly all items were hubbed. Generally, companies worked towards the same target buffer levels for hubbed and non-hubbed components. IBM was the only company that differentiated its target buffer levels based on the pipeline strategy involved.

many cases Sun worked towards two, three, or even five shipments a week.[42] On the other hand, Apricot worked towards a mixture of ten day and five day target buffer levels[43] and, mainly due the low volumes required, some of the pipelines at Apricot involved lower shipment frequencies than at the other focal companies. Thus, where other companies worked towards weekly or bi-weekly shipments for certain components, in some cases the equivalent pipelines at Apricot involved shipments every 20 days. However, for most material inputs, the shipment frequencies at Apricot were in line with frequencies in other focal companies.

Table 5.3 summarises the key logistics data and provides an insight into the way that the logistics of material inputs from different source regions was managed.[44] The first column lists the various material inputs. The second column lists the target buffer levels (average for respondent companies). The third column lists the target number of days between shipments (average for respondent companies). Finally the typical preferred modes of transport are listed in column four.

[42] Furthermore, for the same reasons, Sun used air freight for the transport of more components than other focal companies.

[43] In many cases the five day figure referred to the buffers stored at Apricot on-site, while the supplier hubbed or stocked certain inventories as well. However, given the small volumes involved, there was often no need to specifically stipulate the size of these inventories at the supplier-end, particularly in case of industry-standard inputs.

[44] With the exception of data on microprocessors and memory, no data are presented on the components for the board assembly lines. Only four focal companies were fully assembling limited amounts of PCBAs on site. Furthermore, the data provided were often imprecise due to the fact that most of the component categories included a large number of components with a high variation in price and geographical origin.

Table 5.3. Summary of key logistics data (averages for focal companies)

Material inputs Far East and Americas	*Average target buffer levels*	*Average number of days between shipments*	*Typical preferred mode of transport*
Microprocessors	4	2	plane
Flat panel monitors	5	5	limited data
Memory	8	3	plane
LCD displays	8	4	no typical mode
Partly integrated portables	10	4	plane
Tape back-up/ autoloaders	9	5	plane
AC adapter	9	5	plane
Hard disk drives	9	5	plane
CRT monitors	9	5	ship
Small plastic metal parts	10	5	no typical mode
Floppy drive	9	5	no typical mode
CD ROM drive	9	5	plane
CD RW drive	10	5	no typical mode
Combo drive	10	5	limited data
Zip drive	10	5	plane
Docking stations	10	5	no typical mode
Joysticks	10	5	ship
Scanner	10	5	ship
Server racks	8	7	no typical mode
Sound/video/graphics cards	9	6	plane
Power supplies	9	6	ship
DVD drive	10	6	plane
Modem/network cards	9	7	plane
Enclosures	9	7	ship
Motherboards/backpanels	9	7	plane
High volume keyboards	10	6	ship
Printers	10	6	ship
Enclosures for portables	10	7	ship
Heat sinks	9	7	ship
Microphone	10	8	ship
Cooling fans FE	10	9	ship
Battery for portable	13	6	no typical mode
Riser cards	10	9	plane
Speakers	13	7	ship
Mice	13	9	plane
Power cables	14	10	ship
Other cables	15	11	no typical mode
Screws and fasteners	35	40	plane
Digital cameras	No data	no data	limited data
Material inputs Europe			
Power supplies	5	2	truck
CRT monitors	8	2	truck
Tape back-up/ autoloaders	8	3	truck

Continues on next page

Table 5.3. Summary of key logistics data (averages for focal companies) (cont.)

	Average target buffer levels	*Average number of days between shipments*	*Typical preferred mode of transport*
Material inputs Europe (cont.)			
m' boards/ backpanels	10	1	truck
Memory	8	3	truck
Enclosures for portables	10	2	truck
Cooling fans	10	2	truck
Hard disk drives	8	4	truck
Other cables	10	2	truck
Printers	10	5	truck
Sound/video/graphics cards	10	5	truck
Material Inputs Ireland and UK			
Packaging	2		truck
Low volume keyboards	2		truck
Country kits	2		truck
CD ROMs (wrapped)	4		truck
Printed media (wrapped)	4		truck
Heat sinks	5		truck
Enclosures	5		truck
Hard disk drives	6		truck
Server racks	6		truck
Small plastic metal parts	9		truck
Modem/network cards	9		truck
m' boards/ backpanels	9		truck
Power supplies	10		truck
CRT monitors	10		truck
Printers	10		truck
Flexcircuit	10		truck
Printed labels	13		truck
Power cables	13		truck
Other cables	13		truck
Cooling fans	came integrated		truck

Source: company interviews

Focussing first on the material inputs manufactured in the Far East and the Americas, most components from these regions involved target buffers of between eight and ten days and between weekly and bi-weekly shipments (averages for respondent companies).[45] The typical mode of transport for most materials from other continents was

[45] The focal companies generally had no precise insight into the inventory levels at suppliers' manufacturing facilities in other continents. Therefore, it is theoretically possible that the supply pipelines involved substantial inventories at the suppliers manufacturing facilities in the Far East and the Americas. However, this was unlikely the case. It would simply not make sense for suppliers to carry the relatively high costs of frequent shipments while, at the same time, to build sizeable sub-optimal inventories at their manufacturing facilities. Customers were constantly sharing information regarding short and medium term

by plane leading to relatively small inventories caught up in transit and relatively small fluctuations in the actual inbound inventory levels. Still, certain components were typically transported by ship (see below).

As regards the material inputs manufactured in Europe, most components again involved target buffer levels of between eight and ten days but shipments were more frequent than in the case of components manufactured in other continents. Shipment frequencies out of Europe ranged from one to five times a week but most pipelines involved shipment frequencies of two or three times a week.[46] All European material was trucked by road/ferry. Material inputs from Europe could generally be trucked over in less than 24 hours, although the delivery lead-time could be longer for products from outside the European Union due to customs formalities.

Finally, regarding material inputs manufactured in the UK and Ireland, although a number of components involved very low target buffer levels, as low as two days (average for respondent companies), most components involved buffer levels comparable to those applicable to items manufactured in other regions. Table 5.3 does not include averages for the shipment frequencies since in most cases the main buffers were positioned at the suppliers' manufacturing facilities and fed directly from the manufacturing lines (see section 5.5.1). Focal companies pulled materials from these suppliers on a daily basis, or even more frequently (with the exception of Apricot, which pulled some material on a less frequent basis).[47] Where the main buffers were not positioned at the suppliers' manufacturing facilities, the hubs or the customers' facilities were typically supplied on a highly frequent basis – often daily or every second day (see

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demand forecasts with their suppliers and providing them with very frequent MRP updates. This enabled the suppliers to tightly plan their production schedules for their combined customer base.

[46] As regards the material inputs manufactured in Europe, in relation to most components it is not possible to talk about a pattern because only one or two of the focal companies were sourcing these components from Europe. Only three component categories involved more than two data points: memory, hard disk drives and power supplies. However, all cases together paint a picture of high shipment frequencies out of Europe.

[47] Thus, most enclosures, racks, heat sinks, configured hard-disk drives, and cables, manufactured in Ireland or the UK, were pulled on a daily basis or even more frequently, from buffers positioned at the suppliers. Similarly, country kits, wrapped media, low volume keyboards and packaging were generally pulled daily, or even more frequently, from very small (true JIT) buffers kept at the suppliers' premises.

Table F.2). The main exceptions included modem/network cards, which were typically shipped on a weekly of bi-weekly basis, and printed labels, which were typically shipped on bi-weekly basis or even less frequently. All material manufactured in Ireland or the UK was trucked by road/ferry.

Again, the general picture is one of modest inbound target buffer levels and high shipment frequencies. Although modest, these inbound target buffer levels were slightly higher than one would expect on the basis of comprehensive logistics management principles alone. However, these buffers did not reflect a sub-optimal supply chain solution. The main reason for the slightly higher levels lay in the BTO production strategies of the microcomputer assemblers.

As discussed in section 4.5.1, in line with textbook NHVP approaches, all focal companies (although not all to the same extent) offered a great variety of product configurations, often customised to individual orders, in combination with extremely short order lead times. At the same time, all focal companies aimed to minimise the inventories of finished computer systems. As discussed, in all cases this combination of objectives was addressed by a BTO production strategy (again, to different extents). The problem was that the focal companies were facing strongly fluctuating and unpredictable demand. The BTO models of the focal companies could handle this without an inefficient use of labour, machinery and the build up of in-process inventories by reducing the number of phases in the production process and numerical labour flexibility. However, as the first upstream function, now the suppliers were confronted with a highly irregular and unpredictable sequence of pulls by the focal companies. In such a situation a virtual elimination of buffer inventories on the basis of the comprehensive logistics management principles would lead to an inefficient use of labour at the suppliers or an increased risk of stock-out. A BTO production system with short order lead times in an environment of erratic final demand simply requires certain buffers between the suppliers and the manufacturing lines of the customer, except in situations of extremely short manufacturing cycles at the suppliers. All this is totally consistent with the comprehensive logistics management principles. In effect, the focal companies were simply trading-off the costs of modestly higher inbound inventories against the loss of market share and revenue due to stock-out.[48]

Thus, the target buffer levels at the focal companies were not merely put in place to time the systems and to compensate for production and transportation time. An important function of the buffers was to deal with strong fluctuations in demand. "The 10 days has to do with the fact that we want to be able to deal with an unexpected spike in demand. ... At a very basic part number level the accuracy in our forecast means that we can spin through the ten days pretty quickly. You could find yourself short" (Interview Walsh, Dell, April 2001).

This partly explains why in many cases the supply pipelines of components manufactured in Ireland, the UK and Europe involved similar target buffer levels to those that applied to inputs manufactured in the Far East or the Americas. Again, many of these components involved target buffer levels of between five and ten days. A number of items manufactured in Ireland or the UK tended to involve lower target buffer levels of (finished) components, notably enclosures, racks, hard disk drives, country kits, wrapped media, low volume keyboard models and packaging. However, in most of these cases the suppliers involved were committed to holding the balance of the generic target levels in the form of unfinished or non-configured components while the final assembly or configuration process was made extremely short and added very limited value.

Thus, Apple, AST, Compaq and Digital were all working towards lower than generic buffers of finished enclosures and/or racks – as low as two days in case of AST and Compaq. At least two focal companies (Compaq and Digital), committed their local suppliers to holding the balance of the ten days generic buffer level in component form. For example, the local suppliers of Compaq were committed to buffer two days of enclosures with some components already assembled (such as the power supply, cables, etc.) and eight days of basic stamped/moulded enclosures. The final assembly was a very

[48] A similar challenge of combining JIT principles, global sourcing and BTO production for a volatile market has been described in an article on the logistics operations at Bose's speaker plant in the USA (Bradley, 1989).

short production cycle involving the assembly of the enclosures and the component parts. Dell, IBM and Sun on the other hand required their local suppliers to hold generic target levels of finished enclosures.[49]

Similarly, Dell, Gateway, Apple and Digital worked towards relatively low target levels of fully configured/pre-assembled hard disks. Three companies mentioned that the local supplier, Quantum, was committed to holding the balance of the 10 days generic target buffer level in non-configured form while the configuration cycle was very short and added minimal value. Compaq, Apricot and Sun on the other hand worked towards the generic target buffer levels of finished hard disks.

Country kits were generally kitted on a true JIT basis and the pipelines generally involved very low levels of finished kits – often a day's worth, or even less. However, the JIT 'manufacture' of country boxes really involved nothing more than a simple packaging process of finished components and in nearly all cases the turnkeys were committed to holding certain target inventories of components for the kits. Where focal companies packed their own country kits, again the companies generally worked towards very low buffers of finished media (shrink wrapped CD-ROM with printed documentation). In most cases the turnkey supply chain managers wrapped the material on demand, one day ahead of supply. However, most turnkey suppliers were committed to holding target buffers at component level. Focal companies mentioned CD-ROM buffers of five to 15 days. Documentation tended to be printed on demand leading to very small inventories at the suppliers.

Similarly, the 'manufacture' of low volume keyboard models generally took place on a true JIT basis involving buffer levels ranging from less than one to two days. However, the process involved no more than the final key-cap printing of semi-finished models and the suppliers were generally committed to holding the balance of the generic target buffer

[49] The difference in target buffer levels among focal companies might be partly explained by variations in the BTO strategies adopted by the focal companies, involving different degrees of fluctuation in production (see section 4.4). In relation to this, a staff member at Apple mentioned that, if the company would operate

levels in the form of blank boards. Finally, packaging tended to be manufactured on a true JIT basis involving buffer levels of less than one to two days. Packaging involved extremely short manufacturing times.

5.5.3 The Effect of Component Characteristics and Contextual Conditions

As explained in section 2.4, the adoption of comprehensive logistics management principles can have different outcomes, depending on a range of component characteristics and contextual conditions. This section will describe how these issues affected logistics management and the geography of the linkages at the focal companies. Before doing this, it is important to reiterate that in all cases the eventual outcome is the result of a complex trade-off in which all these issues are considered simultaneously and where the individual component characteristics and contextual conditions can have diverging effects. It is therefore not always possible to isolate the effect of a certain characteristic, and to understand its impact on the actual outcome one has to look at the constellation of issues.

Regional difference in labour costs was a force that tended towards an increase in the linkage distance. Producers in other regions, particularly in the Far East could offer material inputs at a substantially lower price than producers in Ireland or the UK, mainly due to far lower wage rates and high flexibility of the labour force.

> A good example is enclosures. We used to buy our metal boxes from Livingston Precision, 20 miles from here. Logistics wise perfect. I can't remember the exact price but, hypothetically, it was something that they were charging £50 for an enclosure. The tooling that we had to have made was costing us about £250,000. If you go to South-East Asia, the tooling would only cost you $200,000 and then you would buy the same enclosure for maybe $40. So there was no comparison, it wasn't even close (Interview Carson, Apricot-Mitsubishi, July 1999).

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the Dell model to its full, Apple's four days buffer of locally produced finished enclosures would be too low (Interview Barry, Apple, December 2000).

The comprehensive logistics management principles were appreciated but, at the same time, the focal companies remained sensitive to differences in price of material inputs. To attain total supply chain cost effectiveness companies balanced the efficiencies in logistics gained by using local suppliers against material cost price advantages gained by using suppliers in low-wage regions. In many cases the optimal solution involved suppliers located in the Far East.

> It [the reason for not sourcing monitors locally] is basically an argument between the actual unit cost and the actual component part in terms of labour content, etc. So if labour content is a high proportion of the unit than it makes sense to manufacture that in a low labour cost arena. ... So you take into account the differential between labour content and the actual transport cost, your [inventory] financing costs, and money while on the sea, etc., etc. (Interview Barry, Apple, Dec. 2001).

Obviously, contextual conditions were changing all the time and focal companies and their suppliers constantly assessed the efficiency of their logistics systems and, as part of this, the geographical configuration of their supply chains. The opening up of Eastern Europe prompted such a reassessment. Suddenly the players were confronted with a low cost production base and a relatively efficient business climate on one-day drive distance. This decreased the relative attractiveness of the Far East as a source for components, particularly for the relatively bulky components that were coming in by ocean, e.g. monitors, scanners, printers etc. This is illustrated by the following quotation:

> The only problem I have with this [using suppliers in the Far East] at the moment is that the pipeline from South-East Asia to the hub is too long. It is the flywheel analogy. The answer is to change the South-East Asian suppliers to Central European suppliers. ... And the reason we are trying to get them from Central Europe is because we look at labour rates for example, the general overhead costs are significantly lower, almost comparable in some cases to the Far East, with the exception of China. ... Take the components that I am particularly interested in, the things that take six weeks to get here. The bulky things, the things that come by ocean, your case, your power supply, your speakers, monitors, those we can't fly and we are particularly interested in looking at them. ... Distance does matter. You can't fly it over. It is not an option. You are talking about metal casings (Interview Flynn, Gateway, Sept. 1999).

As described in the previous section, whatever the geographical source of the components, the inbound inventories were managed very tightly. In accordance with the comprehensive logistics management principles regarding unit value (Christopher, 1992), most tightly managed were the inventories of components with a high unit value. Thus, as regards material inputs manufactured in the Far East and the Americas, the inventories of high value microprocessors, flat panel monitors and memory tended to be managed most tightly, involving low buffers and multiple flights a week (see Table 5.3). On average the focal companies and their suppliers worked towards microprocessor inventory levels that fluctuated between four and six days, flat panel monitor inventory levels that fluctuated between five and ten days, and memory inventory levels that fluctuated between eight and 11 days. Thus, the high value of these components led to a higher shipment frequency, which should theoretically increase the tendency towards proximity. However, this force towards proximity was simply outweighed by the labour cost savings involved in producing these items in the Far East in combination with the relatively low costs involved in transporting these items frequently by air.

On the other hand, the inventories of items with a low unit value incurred limited total inventory costs and were managed less tightly, *ceteris paribus*. Thus, as regards material inputs manufactured in the Far East the inventories of mice, cables and screws were managed least tightly. On average the focal companies and their suppliers worked towards mice inventory levels that fluctuated between 13 and 22 days and cable inventories that fluctuated between 15 and 25 days while inventories of screws and fasteners were targeted to fluctuate between 35 and 75 days. Similarly, as regards locally manufactured inputs, the least tightly managed items were low value printed labels and cables.

The effect of bulkiness of individual components (Lubben, 1988; McKinnon, 1997) is most clearly illustrated by packaging material. Packaging material, although of low unit value, required much warehouse space, thereby incurring extremely high inventory holding costs. Thus, packaging tended to be manufactured on a true JIT basis involving buffer levels of less than one to two days and one or more shipments a day. Simply, in the case of packaging the characteristic of bulkiness weighed stronger than the characteristic of low unit value resulting in true JIT supply.

The bulkiness and weight of the components had also a more indirect effect on the logistics management and the geography of the supply linkages – via their implications for the mode of transport. Most material inputs manufactured in the Far East or the Americas were typically transported by plane leading to low in-transit inventories and low fluctuations in the target buffer inventories. Companies mentioned transit times ranging from three to five days including time lost at customs authorities on both sides.[50] However, airfreight rates rise steeply for components with a high physical volume or weight with the result that for many components airfreight is simply not a option on a continuous basis.

The alternative was ocean freight. The downside of ocean freight is that it involves substantial in-transit inventories. Companies typically mentioned transit times of four to five weeks in case of ocean freight from the Far East and two to three weeks from the USA. Furthermore, ocean freight involves larger fluctuations in the actual inbound inventory levels than airfreight, even though the target buffer levels might be similar. At any time there would be several weeks of inventory in-transit that could not be turned off. This created a flywheel effect in the inbound logistics pipeline. In case of a downturn in demand, the actual inbound inventory levels could potentially rise well above the target buffer levels. Likewise, a surge in demand could potentially lead to shortages.

In spite of these downsides, for many components with lower value-to-weight or value-to-bulk ratios the trade-off went in favour of ocean freight. Thus, computer enclosures, enclosures for portables, power supplies, cooling fans, heat sinks, CRT monitors, high volume keyboards, joysticks, microphones, scanners, speakers, printers and power cables were typically transported by ship. The downsides of ocean freight were reduced by using different ocean-freight services, offering a range of transit times and by the occasional

[50] Although different freight methods involved different lead times. For example, IBM used various services with transit times ranging from 48 to 72 hours (depending on the exit point) to five to seven days. Similarly, Apple used consolidated air freight as well as expedite or express air freight.

use of airfreight services. Thus, in a situation of fairly stable demand patterns components were transported by ocean but if there was any tightness in the supply chain due to an increase in demand, companies resorted back to airfreight. Similarly, towards the end of the component life cycle companies resorted back to airfreight and tightly managed the inventory levels during the final stages of a particular supply chain. However, a significant surge in demand could still lead to shortages and required expensive expediting exercises involving airfreight.

In other cases, the combination component characteristics and regional labour cost differences meant that the optimal supply chain solution involved the use of local or regional suppliers. For example, as outlined, most focal companies sourced enclosures from local suppliers.[51] In this case the relatively high bulkiness of the enclosures presented a strong force tending towards proximity while the labour cost savings associated with production in the Far East would have been partly offset by the fact that, on a routine basis, the product could only be transported by ocean, leading to high in-transit inventories and higher fluctuations in the actual buffer inventories. Similarly, a number of monitor suppliers operated local or European manufacturing facilities.[52] Here, the relatively high bulkiness and high value of the monitors presented a strong force

[51] A number of interviewees stated that the optimal solution involved enclosure suppliers in the Far East. However, the reason for this most likely lay in the more limited volumes required – volumes that did not warrant the costs of developing a local source and the cost of a second tool. In those cases it was more economical for companies to consolidate their company-wide enclosure requirements for a particular model at a single supplier plant, thereby enjoying economies of scale. Thus, Digital, Apricot, Gateway and Packard Bell imported most of their volume enclosure models from the Far East. However, the output of Digital and Apricot was small in comparison to most of the other focal plants. Similarly for Gateway the main reason for not using local suppliers lay in the limited volumes. "Because our volumes in Europe for the first four to five years did not really merit going out trying to get a [regional] supplier. But it is getting to a stage now, where we have 30 per cent year-on-year growth, that we need to look at a [regional] supplier. We probably won't save on cost of goods, but we certainly will save on transit or lead-time and potentially transit costs" (Interview Flynn, Gateway, Sept. 1999). Packard Bell was in the process of contracting a local supplier (Fullarton) for the production of volume enclosure models. Apple imported its world wide enclosure requirements for the new I-Mac range from a plant located in the Far East so Apple could enjoy economies of scale (interview Barry, Apple, December 1999). As regards the less current enclosure models and server racks, as discussed, these were often imported from the USA. Obviously, this had not much to do with low labour costs. Rather, the volumes involved simply did not warrant the development of a second source locally.

[52] IBM had even been instrumental in the decision by Korean Chungwa to set up a picture tube manufacturing plant in Scotland. Chungwa was to supply tubes to Lite-on in Scotland who, up to May 1998, assembled monitors for IBM. However, the Chungwa plant did not materialise as Lite-on got into

tending towards proximity. And, again, the labour cost savings associated with production in the Far East were partly offset by the fact that, on a routine basis, the relatively heavy monitors had to be transported by ocean.

The greater proximity of the enclosure suppliers and some monitor suppliers is not explained by their relatively lower value-to-weight or value-to-bulk ratio and the old idea that inputs with a higher value-to-weight ratio are simply able to bear higher transportation costs, as suggested by O'Farrell (1980) and Lever (1974) (see section 2.4.4). The point is that low wage rates, in combination with competitive and well established international air-freight infrastructures (in relation to this see Hamilton, 1995; Hise, 1995), have made distant countries such as the East and South-East Asian NICs, increasingly attractive locations for labour intensive component production. However, due to the structure of airfreight rates, this applies less to components that are physically relatively big. Thus, here the point is not that high value-to-weight components can necessarily bear higher transport costs than low value-to-weight components. Rather, the point is that small, virtually weightless, components can be transported frequently and speedily over great distances relatively cheaply, while many bulky components cannot.

Another component characteristic mentioned in section 2.4.4 was the minimum efficient scale of production. The point was made that in order to reach the minimum efficient scale of production suppliers need to have several customers which can mean that suppliers are located at considerable distances from some of their customers (Bordenave and Lung, 1996; Jones and North, 1991; McKinnon, 1997; Milne, 1990; Morris, 1992b; Schamp, 1991). This issue was probably not the principal factor in the explanation for the low proportion of components sourced from Ireland and the UK. As outlined, the majority of components were sourced from other continents. Thus the issue would only be the primary factor if the minimum efficient scale of producing a certain component exceeded the level of demand in the European market. It is extremely unlikely that the

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financial difficulties due to the economic crisis in Asia, and closed its Scottish plant in May 1998 (*World Socialist* web site, www.wsws.org/news/1998/ july1998/scot-j08.shtml, accessed 31-03-01).

minimum efficient scale of producing the often standardised components would not be reached by producing in Europe for the European market.

The issue does explain some of the detail in the geographical configuration at a national and regional level. The differences in the minimum efficient scale of production do mean that suppliers of some components need the business of more customers than suppliers of other components. Some components or services can be produced or offered efficiently at a relatively low scale, requiring only one customer. As a result, suppliers can set-up relatively small operations in relatively close proximity to individual customers. This explains why, as outlined, the focal companies tended to use suppliers located in very close proximity for country kits, keyboard localisation and packaging. Producers of components with a higher minimum efficient scale often need a level of business that can exceed that offered by one or a few individual microcomputer companies. As a result, the larger operations of these suppliers are located at greater distances to at least some of their customers – totally consistent with the comprehensive logistics management principles. Thus, for motherboards, monitors, enclosures and higher-end technology components the focal companies maintained linkages with suppliers located at greater distances, often located in a different country on the British Isles. According to the interviewees, many of these suppliers set up a local manufacturing facility because of the potential market offered by all microcomputer companies (and in some cases other electronics companies) in Ireland and Scotland and in some cases beyond that, in Britain and Europe.

The variety of options per component category was a relevant issue as well. As explained in section 2.4.4, the greater the variety of options, the greater the incentive to delay the final assembly of component materials into finished components (Van Hoek, 1998). The greater the delay in final assembly, the greater the shipment frequency, the greater the driver for buyer-supplier proximity. As shown, the components with a high variety of options – country kits, shrink-wrapped media, low volume keyboard models and the customer configured hard disk drives of Quantum – were indeed produced on a true JIT or virtually true JIT basis, generally by local suppliers. Holding standard target buffer levels of these components in all their possible configurations and languages would greatly increase the inventory holding costs.[53] As shown in the previous section, the local supplier facilities were precisely involved in the delayed or postponed final assembly or configuration activities, while they were generally committed to holding higher buffer levels of unfinished or non-configured components, often produced in other regions.[54] Clearly, in case of the more standardised components of the kits, such as blank keyboards and mice, the forces tending towards an increase in the linkage distance, notably labour cost savings in other regions, were greater than the forces tending towards proximity.

Finally, we turn to the contextual issue of regional industrial technical capabilities. As discussed in Chapter 2, one of the reasons why the adoption of comprehensive logistics management principles does not necessarily lead to buyer-supplier proximity can be that the required technology is simply beyond the limited industrial capabilities of a region (McCann and Fingleton, 1996; Morris, 1992a; Phelps, 1993a; Phelps, 1993b; Reid, 1995). Obviously, this is not a valid explanation for the limited local linkages of the microcomputer hardware industry in Ireland and Scotland. Both countries have built up an impressive high-tech electronics component production and development capability, notably in the area of microprocessors and other semiconductors. Furthermore, many of the components that were imported from other regions were once manufactured in Ireland and/or Scotland – for example, packaged microprocessors, hard disk drives, mice, keyboards and cables.

This section clearly showed that component characteristics and contextual conditions affected the way companies managed their inbound logistics and the geography of the supply linkages. In many cases these characteristics led to logistics systems that diverged substantially from the prototypical true JIT system. However, in all cases the divergences were totally consistent with the comprehensive logistics management principles.

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[53] With respect to country kits, an extra reason for this is the increase in physical volume during final assembly. Packing the individual components into a box greatly increases the transportation and warehousing costs – an additional incentive for postponed assembly near to the customer (Van Hoek, 1998).

5.6 Relevance of Other NHVP-Related Issues Believed to Lead to an Increase in the Linkage Distance

As discussed in section 2.4.5, apart from the information exchange and logistics related drivers for buyer–supplier proximity, some authors have pointed out that other aspects of NHVP-related supply chain strategies, notably the reduction of the number of suppliers per component (from multiple sourcing to single sourcing) and company-wide consolidation of purchases, might actually lead to a reduction in local sourcing. As regards the reduction of the number of suppliers per component the idea is that this will lead to larger suppliers that will restructure their global operations more independently of individual customers' locations (Glasmeier and McCluskey, 1987; Hudson, 1994; Morris, 1992b; Phelps, 1993b; Schamp, 1991). As regards the company-wide consolidation of purchases the idea is that the consolidation will lead to a reduction of supplier plants and therefore an increase in the linkage distance to individual assembly plants of the customers (Clarke and Beany, 1993; McCann, 1996; Morris et al., 1993; Munday, Morris, and Wilkinson, 1995; Phelps, 1993b; Pike, 1998). Furthermore, centralised purchasing systems have been related to a lack of subsidiary autonomy, believed to lead to lower levels of local sourcing (McCann, 1996; McCann, 1997; Phelps, 1993a).

The validity of the ideas for a large part hinges on the number and location of the *plants* that remaining individual *suppliers* will operate to service their customers. In this respect the interviews made clear that assemblers did prefer suppliers that can supply the various assembly plants from plants located in a number of different regions. In this regard, a triad manufacturing presence remained an important plus in the process of supplier selection and all focal companies acknowledged that they had regular discussions with existing or potential suppliers regarding investments in regional manufacturing facilities. As a way of illustrating this point, Table 5.4 presents the suppliers with manufacturing facilities in Ireland or the UK that operated plants in other regions to supply other assembly plants of the focal companies. Clearly a great number of local suppliers

[54] The exceptions included inputs for the kits or shrink-wrapped media that, in turn, involved a high variety of options. For example, the printing of documentation in the various European languages was generally

employed a multi-regional production configuration to serve the various plants of the focal companies and in relation to some component categories, such as enclosures, the trend was towards an increased use of global suppliers with multi-regional capability (see section 5.2.2).

At the same time, as outlined in section 5.2, the majority of suppliers supplied their customers in Europe from manufacturing facilities in the Far East. However, in these cases the linkage distance was best explained by reference to production cost differentials, rather than by the notions of elimination of linkages or company-wide consolidation of purchases. Company-wide consolidation of purchases did play a role in a small number of cases where, due to the limited component volumes involved, companies choose to source their requirements for Europe from the same plant that supplied the requirements for the USA. It was exactly for this reason that many sever racks and other low volume enclosure models were sourced from manufacturing plants in the USA.

Table 5.4. Local suppliers operating plants on other continents to supply plants of the focal companies on other continents*

Component category	Supplier
Complete computer systems	Celestica; Fullarton; Inventech; Mitac
Enclosures and racks and small plastic and metal parts	APW (High Speed, C-Fab, Horman); Bermo; Foxteq; Fullarton; LMS Beach; Birkbys
Motherboards, backpanels and riser cards	AVEX; Celestica; CTS; Jabil Circuit; SCI; Solectron
Microprocessors	Intel
Memory	Motorola
Hard disk drives	Quantum (MKR); Seagate
Cooling fans	APW (McLean Midwest)
Modems and network components	3-Com; Cabletron; Madge networks (Celestica);
Cables and interconnect	Amphenol; Keytech; Methode; Molex; Phoenix; Volex
Displays	LG Electronics; Samsung; Tatung; Sony
Keyboards	Alps; Chicony; Lite-on; NMB
Printers	Epson
Media	Modus Media; Gardener Gibson; Printech; US Print
Kits	BG Turnkey; Modus Media
Packaging material	Ire-Tex; Smurfit
Sub-assembly services	Turnkey

Source: company interviews
Note: *companies mentioned in the table supplied at least one other manufacturing facility of at least one focal company.

done on a true JIT bases.

The idea that the low levels of local sourcing were the result of a lack of subsidiary autonomy, related to centralised purchasing systems, does not hold much ground either. As discussed in section 4.5.4, it was true that supplier selection was carried out on a global basis. The function was strongly centralised. The global purchasing groups were typically based in the USA and European operations had a relatively low level of autonomy in relation to most components. However, at the same time, the centralised purchasing system did involve a substantial amount of subsidiary consultation which provided European operations the opportunity to influence the selection process to some degree. Regional procurement groups were in regular communication with the global procurement functions and in many cases this communication was formalised through the regional involvement in the global commodity councils.

Thus, purchasing decisions were taken at a global basis but European operations had an input in the decision process. Purchasing did take account of the comprehensive logistics management principles. However, the trade-off of all relevant factors simply did not lead to high levels of local sourcing by the European operations. This argument is supported by research carried out in a different context. Angel and Engstrom (1995) showed that microcomputer assembly plants in the USA were characterised by local sourcing patterns similar to those of the European operations. Thus, even plants located near the centre of decision-making in the USA were not characterised by higher levels of local sourcing.

5.7 Dynamic Indicators of Indirect Regional Development Effects.

As discussed in section 2.6, the indirect effects of MNEs on regions can be assessed in a 'static' or a 'dynamic' framework (Turok, 1993; Young, Hood, and Peters, 1994). So far this chapter has dealt with static indicators of development such as the number of local linkages and the proportion of total material inputs sourced in the local or regional economy. This section will focus on dynamic indicators of development, i.e. the impact of the focal companies on the quality and competitiveness of their suppliers in Ireland and Scotland. To prepare the ground for this, the section will start with some additional comments regarding the static indicators.

As described, the focal companies sourced only a relatively small proportion of their total material input requirements from the local economy. On average, only ten per cent of the parts and components sourced by the focal companies in Ireland were manufactured in Ireland while the average figure for the focal companies in Scotland was even lower. The regional supply network included 109 companies and 125 plants, of which 57 in Ireland and 49 in Scotland (and about 20 in England and Wales). However, the scope of the activities in Ireland and Scotland was small. The only components that were mainly sourced from suppliers in Ireland or Scotland were enclosures, packaging, media, kits and low-volume keyboards. Furthermore, the actual production activities in many plants were very limited or added limited value to the product.

An attempt was made to establish the extent to which the demand of the focal companies had led to an expansion of production capacity in the regional supply base, either foreign-owned or indigenous. The answers showed that linkages with the focal companies nearly always led to, at least, the establishment of extra production lines at the local suppliers. It proved, however, impossible to precisely link the demand of a focal company to the opening of entirely new plants or companies, either foreign-owned or indigenous. In some cases the opening of new supplier plants could be directly linked to an individual focal company, notably where the supplier plants were involved in activities characterised by a low minimum efficient scale of production, as in the case of the kitting plants of BG Turnkey and Modus Media. However, according to the interviewees, in many cases the investments by suppliers was related to the potential business offered by several microcomputer companies in Ireland and Scotland (and beyond) and in some cases by companies in other segments of the electronics industry as well. Even if investment could be brought back to the initial business offered by, and discussions with, one of the focal companies, in many cases, suppliers' investment decisions were based on the wider market for their product in the region.

In spite of this ambiguity, the interview data show that the presence of the 11 focal companies resulted in the establishment of a substantial number of supplier companies in the region. Thus, according to the interviewees the investments by the following MNEs was primarily related to the presence of one or more of the microcomputer assemblers in Ireland and/or Scotland: Alps Electric, APW, Trend, Lite-on, LMS-Beach, Modus Media, Munekata and SCI in Ireland, Amphenol, APW, Bermo, Chicony, CTS, Foxteq, Inventech, Jabil Circuit, Modus Media and US Print in Scotland and Celestica in England. Furthermore, a number of other MNEs originally invested in the region to supply one or more of the focal companies but have since lost that business. Similarly, the formation, or most of the recent growth, of the following indigenous manufacturers was related primarily to the demand of the focal companies: A&W Fullarton, BG Turnkey, Ballymount, Birkbys, Brands, Chip, Datapackaging, Fullarton, Horman Electronics, Printech and Turnkey.[55] Furthermore, the growth of the two logistics companies, IEC and Walsh Western, was strongly linked to the focal companies as well.

Turning to the dynamic indicators, as mentioned in section 2.6, based on the ideas of Dicken (1998), the view was taken that linkages involving indigenous companies are more beneficial for regional development than linkages with local subsidiaries of other MNEs. The idea is that indigenous companies generally locate a greater range of functions with a higher degree of authority within the region than foreign multinationals. As a result, indigenous companies are likely to be more embedded and less footloose, increasing the chance of technology spillover and further investments. It must be said however that this does not mean that the creation of local linkages with subsidiaries of other MNEs can not have dynamic consequences for regions and/or countries (see below).

Section 5.2 already showed that many of the local suppliers were actually subsidiaries of foreign multinationals. A count of the companies in Appendix D shows that of the 49 suppliers with manufacturing facilities in Ireland, 28 were foreign owned at the time the interviews were conducted.[56] Likewise, of the 50 suppliers with facilities in Scotland, 26

[55] Some of these companies were subsequently taken over by foreign MNEs.
[56] Scottish companies are here counted as foreign and BG Turnkey is counted as indigenous on the basis that the head-office of this division of Banta was still based in Cork.

were foreign owned, while a further three companies were English based.[57] Finally, 13 of the 18 suppliers with manufacturing facilities in England and Wales were foreign owned. Thus, the majority of the local suppliers were subsidiaries of foreign MNEs and, in the context of the process of corporate consolidation of purchases, the trend was towards a growing role of subsidiaries of MNEs (see section 5.2.2).

Believed to be an important medium for dynamic demonstration effects or "tutoring effects" (Cooke and Morgan, 1998), the focal companies were asked to outline their 'supplier development' efforts, defined as "policies, procedures and practices for assessing and improving supplier capability and performance in multiple areas such as quality, design support, and delivery" (Jarayam and Vickery, 1998). All nine focal companies that answered this question gave evidence of active supplier development. Most development activity took place within the framework of some form of continuous supplier improvement programme discussed during the periodic supplier reviews. Typically, the partners rated suppliers' performance in a range of areas, e.g. price, product quality, delivery, communication, environmental standards, and discussions took place as to how to improve on this performance. Efforts were often limited to merely making suggestions for corrective action but could also involve more hands-on assistance, depending on the problem and the capabilities of the supplier. Thus, all companies mentioned that, where necessary, their quality engineers, purchasing people and logistics staff had visited suppliers' plants in order to advise and assist suppliers with improving the efficiency and quality of the production processes, business methods and logistics systems.

Supplier development could also take place during the process of new supplier approval and the ramp-up of a supplier's production facilities. Focal companies also provided their suppliers with technical information regarding new component product and process technologies. Finally, supplier development could be part of the introduction of new processes at the focal companies. For example, according to one interviewee, the

[57] Here, Fullarton is counted as indigenous on the basis that the head-office of this division of an English based company was still located in Scotland.

education sessions and assistance in the context of the implementation of e-business resulted in a substantial improvement in supplier capability.

The organisation of supplier development differed from focal company to focal company but typically there were no specific units with supplier development responsibility. Supplier development teams were set up for the purpose – their composition and size depending on the particular needs of the supplier. Nearly all supplier development efforts involved bilateral relationships – none of the focal companies had organised the kind of formal supplier groups or associations as outlined in see section 2.6.

In order to further assess the dynamic indirect effects and the actual impact of the linkages on the quality and competitiveness of the regional suppliers an attempt was made to measure the extent to which the linkages with regional suppliers involved adaptation on the part of the supplier. Partly based on the categorisation by Gadde and Hakansson (1993), interviewees were asked whether, in order to become approved suppliers, individual suppliers had had to adapt by upgrading or expanding various aspects of their business, i.e. process technology (e.g. new machinery or equipment), product technology and organisational routines across all functions.

Before analysing the results, a number of comments need to be made. First, the format of the particular question was incapable of capturing all supplier upgrading as a result of production linkages. Interviewees pointed out that supplier upgrading happens continuously over the lifetime of the partnership, rather than only during the period of supplier approval. This was acknowledged and the answers really relate to the question whether supplying a focal company had meant that individual suppliers had adapted by upgrading various aspects of their business.

Secondly, it was not always possible to claim that a particular upgrading was the result of dealing with one of the focal companies. In many cases it is a two-sided issue. The focal companies typically outline their own technological road maps and, based on that, and the road maps of other customers, individual suppliers decide on their own strategic directions. However, in general, interviewees were able to indicate where a particular upgrade was strongly related to supplying their company.

Thirdly, as mentioned earlier, the view was taken that linkages involving indigenous companies are more beneficial for regional development than linkages with local subsidiaries of other MNEs. Because of this, and in order to save interview time, in a number of companies the question on upgrading at regional suppliers was restricted to indigenous and/or formerly indigenous suppliers[58] and the data presented below pertain to upgrading at these suppliers only. In hindsight this was unfortunate. As described above, many local suppliers were subsidiaries of MNEs and the interviews at a number of focal companies made clear that supply linkages with most of these local subsidiaries often involved substantial upgrading as well. The impact on the region would most likely have been greater and longer lasting had these local suppliers been indigenous companies. However, upgrading at local subsidiaries of MNEs might well represent a dynamic consequence for the region or country, notably through the learning effects for the local workforce. Hence, it has to be stressed that the indirect dynamic consequences of the focal companies are more extensive than the effect on indigenous companies, as presented below.

Finally, the question on supplier upgrading was only posed in relation to companies that were supplying the focal companies at the time of the interviews. Upgrading effects on past suppliers were therefore not measured. This is another reason why the data presented below undervalue the focal companies' dynamic contribution to development via supply linkages.

[58] Formerly indigenous companies were included as well since in many cases the focal companies' impact operated at the time before the take-over by a foreign MNE. In fact, the impact of the supply relation on upgrading might well have been instrumental in increasing the attractiveness of the indigenous supplier for take-over.

Table 5.5. Upgrading effects at indigenous and formerly indigenous suppliers.

	Upgrade process technology (machinery)	Upgrade product technology/range	Upgrade organisational routines
Suppliers in Ireland			
APW (C-Fab)			
APW (Horman Electronics)	x	x	
Ballymount (Trend)	x		x
BG Turnkey services	x	x	x
Burex			
Chip			
Colorman	x		
CTM Southborough	x	x	x
Cuspal			
Datapackaging (Trend)	x	x	x
EPC			
Fitzpack	x		x
Fullarton			
Hiterm			
Ire-tex Group (ILP)	x		
Irish Moulded products			
Keytech	x	x	x
MacB, Cork, Ireland			
McDonald Printing			
Printech	x		
QEF			x
Rennicks			x
Smurfit	x	x	x
Techmatic			
Tech-source			x
Top Tech	x		
Walsh Western	x		x
Worldmark Group (Industrial Print)	x		
Suppliers in Scotland			
APW (High Speed Production)	x	x	x
Arkol			x
BG Turnkey Services	x	x	
Birkbys (England based)	x	x	x
Brands Electronics	x	x	x
Clairemont Electronics		x	
Dewar Brothers			
Elcomatic	x		
Fife Fabrications		x	x
Foamplus, Linwood, Scotland	x		
Fullarton Computer Industries	x	x	x
Geltron (England based)			
Hamilton Packaging			

Continues on next page

Table 5.5. Upgrading effects at indigenous and formerly indigenous suppliers (cont.)

	Upgrade process technology (machinery)	Upgrade product technology/range	Upgrade organisational routines
Suppliers in Scotland (cont.)			
KWR			
Livingston Precision	x		
MacFarlane (A&W Fullarton)	x		x
Printech	x	x	x
Rexem Corrugated (John Horn)			
SCA	x		
Scotfoam			
Simclar		x	x
Smurfit Corrugated UK	x		x
Sonnel			
Thompson Litho	x		x
TR Fastenings			x
Turnkey			
Volex (Enland based)		x	
Worldmark Group (Donprint)		x	

Source: company interviews

Note: 'x' denotes that at least one focal company mentioned a particular type of upgrade in relation to an individual supplier.

The results are summarised in Table 5.5, where each 'x' indicates that at least one focal company mentioned a particular type of upgrade in relation to an individual supplier. Clearly, according to the ten focal companies that answered this question, the local linkages involved significant upgrading of the indigenous supply base. Of the 56 indigenous, or formerly indigenous suppliers in the list, 37 were believed to have upgraded at least one aspect of their business while many had upgraded several aspects. All focal companies were responsible to some extent, although the more recently established focal companies had impacted on a smaller amount of suppliers than the longer established focal companies. This was partly a result of the fact that many local suppliers, once they had upgraded for one (longer-established) focal company did not have to make the same upgrade for another focal company. Furthermore, the impact of Packard Bell was limited simply because of the fact that it was still in the process of establishing linkages with local suppliers.

As regards process technology, upgrades mentioned included the installation of new sheet metal presses, new tooling technology, paint shop improvements and testing equipment at the enclosure manufacturers; new machinery for the integrated manufacturing of corrugated/ gloss paper and new colour technology at the packaging suppliers; new testing equipment at the turnkey companies; new litho-printing technology at the printing suppliers; new laser printing technology and testing equipment at keyboard localisers and new test equipment at PCB assemblers. In at least one case, the focal company financed some of the testing equipment and tooling. Furthermore, many suppliers had upgraded their quality control systems and improved process efficiencies by changing plant lay-out and installing new information technology.

A substantial number of suppliers upgraded their product technology as well, although in most cases this generally involved an expansion of the product range or a diversification of the business activities. Thus many enclosure manufacturers had started off as sheet metal companies, slowly diversifying into sub-assembly and developing into, in some cases, integrated system builders. Similarly specialised out-plant labour service providers increased their skills base and subsequently entered into new ventures. Supply chain managers developed into turnkey supply chain managers very much as a result of the link with the focal companies. Walsh Western, initially purely a warehousing company started to carry out value added activities.

Finally, for most suppliers, dealing with the focal companies involved an upgrading of their organisational routines. Almost invariably dealing with any of the multinational microcomputer companies meant that suppliers had to adapt their systems to be able to 'communicate' and do business with the focal companies. Although this might have meant an upgrade for the supplier, the interviewees were specifically asked to indicate only those cases where the linkage involved a significant 'upgrade' at the local supplier. The results indicate a substantial demonstration effect on indigenous suppliers. Most frequently mentioned were upgradings in the warehousing and supply functions, notably the implementation of JIT supply systems and hubbing. This involved new organisational and financial structures and new communication systems.

Clearly, the supply relations and supplier development efforts had a significant impact on the quality and competitiveness of the indigenous suppliers. As a result, and again for a large part on the back of the market opportunities offered by the focal companies in other regions, a number of indigenous suppliers were able to penetrate foreign markets using various routes such as export, overseas acquisition, direct investment abroad and joint ventures or other alliances. The clearest examples are outlined below.

Fullarton is the most successful example of a Scottish based (although now English owned) supplier that has benefited from the presence of major microcomputer assemblers in Scotland. The company was founded in 1978 and started producing PC enclosures in the early 1980s. Over the following two decades it diversified into the production of other mechanical microcomputer components and complete system assembly, supplying IBM, Digital, Compaq as well as Intel in Ireland. In 1994 it opened a new plant in the USA partly to support the American facilities of its main customers, notably IBM that had facilitated international contact via its commodity council. In 1995 the UK Laird Group acquired it. In 1997 the company acquired Mimtec, another large Scottish enclosure manufacturer. During the last part of the decade the company opened plants in Ireland, China and the USA. In 2001 the company employed 2,000 people world-wide (*Fullarton web site*, www.fullarton.com, accessed 10-04-01).

Scottish based Donprint was founded in 1979 to produce product identification material for the electronics and automotive market. In 1995 it became part of UK based Jarvis Porter labelling company. Irish based Industrial Print was founded in 1977 to produce high-tech labels and metal badges mainly for the electronics industry, including some of the large microcomputer manufacturers. In 1997 the company was acquired by Donprint to complement the electronics division that was bought out by the Scottish management to form the Worldmark group in 1999. During the 1990s, the company increasingly penetrated foreign markets, partly by supplying the overseas sister plants of the focal companies in Ireland and Scotland. International sales and service centres were followed by the opening of the first plant in the USA in 1995 and subsequently in Wales, Hungary and Mexico (*Worldmark web site*, www.worldmark.com, accessed 09-10-2001).

Brands was established in 1986 by two brothers. Initially carrying out service and repair work for IBM, during the 1990s the company diversified into assembly and supply-chain-management for the electronics companies, including Compaq and Digital. In the second half of the 1990s it internationalised by opening new facilities in China, the USA and Mexico. "A well-founded alliance with a US customer [Compaq] clearly made this move to the USA easier – a technique that has since been replicated for its Mexican operation based in Guadalajara" (*The Sunday Herald* [online], www.sundayherald.com/ news, 22-02-01). Simclar, another Scottish based subcontract manufacturing services company, grew partly on the back of local electronics MNEs, notably Digital. The company, established in 1976, initiated a global expansion programme at the end of the 1990s, beginning with a new manufacturing facility in the USA (*Simclar web site*, www.simclar.com, accessed 02-04-01)

In Ireland a local entrepreneur founded BG Turnkey Services in 1986, starting with simple assembly activities for Apple in Cork. During the 1980s and 1990s the company took on more sophisticated kitting, printing and testing activities and developed into a turnkey supply-chain-management and logistics provider servicing all the focal companies in Ireland as well as other MNEs with production facilities in Ireland, such as Microsoft, Oracle and Lotus. Initial international expansions concentrated on Scotland and Europe, where customers included Sun and Compaq. In 1996 the company, employing over 500 people, was acquired by USA based Banta but Cork remained the world-wide headquarters for the BG Turnkey Services Group.

Keytech was set up by two Irish entrepreneurs in 1994 as a one-room operation in Limerick supplying Dell with cable assemblies. Keytech quickly expanded in the area of enclosures and system assembly through take-over of three other indigenous companies in the period 1996-1997. In 1997, the company opened a manufacturing facility in Malaysia to support Dell and Gateway, employing 500 people in 2001. In 1998, the company opened a new plant in the USA to complement its sales offices in Austin (*Microsoft web site*, www.microsoft.com/ uk/ business/ manufacturing/ items/ 304.htm, accessed 02-04-01).

Dublin based Printech was founded in 1978. Initially a printing company supplying the high-tech companies in Ireland, during the 1990s the company developed into a turnkey supply-chain-manager of media and, at the end of the decade, hardware. At this time it rebranded itself as Sercom Sollutions. After initial experience with MNEs in Ireland, notably Microsoft, Lotus, Apple and Intel, the company expanded internationally with a manufacturing facility in Scotland to supply IBM and later a new plant in the USA. It also set up a new facility in Limerick to supply Dell. By 2001 it employed over 500 people world-wide (Interview O'Grady, February 2001).

The Irish based Ire-Tex Group was originally founded in 1974 as the ILP group, manufacturing labels and distributing packaging. In 1983 the company diversified and started to concentrate on packaging for electronics companies, notably Dell, Gateway and Intel, operating three plants in Ireland. In the second half of the 1990s it set up a joint-venture company in Malaysia to supply Dell and Gateway and subsequently expanded with facilities in the Czech Republic, the USA and China (*Ire-Tex web site*, www.iretex.com, accessed 23-05-02). Smurfit was another indigenous packaging company that supplied plants of the focal companies in other regions. However, the internationalisation of this highly successful global company should not be attributed to its links with the focal companies.

The most successful examples of Irish companies internationalising on the back of the microcomputer assemblers are to be found in the area of logistics. Before being taken-over, both IEC and Walsh Western developed as Irish-owned transport and warehousing companies into world-class international third party logistics and supply chain management providers. For IEC the break came in the early1990s when Apple requested its suppliers to take back inventory and IEC offered to take it for them (Dunne, 1998). Since then the company experienced rapid growth, providing services to main electronics companies in Ireland, including AST and Dell, Gateway and Intel. In the mid-1990s the company started to expand abroad with new facilities in Scotland – where IBM and Compaq, Digital and later Packard Bell became important customers – England, Wales, and Europe. During the same period the company set up facilities in the USA, for example a new hub to service Dell, and the Far East. In 2000 the company, employing 2,600 people world-wide, was taken over by USA based Flextronics. Similarly, Walsh Western, after servicing customers in Ireland, that over time included AST, Dell, Apple and Intel, expanded internationally, notably in Scotland where Packard Bell became one of its main customers. In 1998 the company was acquired by UK based Exel Logistics (Cannife, 1998).

Thus, the microcomputer companies in Ireland and Scotland sourced a relatively small proportion of their material input requirements from local suppliers and the scope of the local supply network was limited. However, the local linkages that were forged, had significant dynamic effects on the supply-base in Ireland and Scotland. This partly supports the more positive ideas expressed by Munday et al. (1995).

5.8 Conclusion

This section relates the empirical findings presented in this chapter to the four research patterns presented in section 2.5 and summarised in Table 2.2. The discussion of the findings in the context of existing literature and theory will be left for the overall conclusions of the dissertation. The situation outlined in this chapter matches closely target research pattern 2b: no significant local linkages – neither comprehensive logistics management principles nor technical information exchange drive proximity, but the principles are appreciated. The findings provide very limited support for the three rival research patterns.

The vast majority of material inputs were manufactured in regions outside Ireland and Britain, notably from the Far East and, to a lesser extent, the USA. The only parts or components characterised by significant sourcing in Ireland and/or Scotland were:

enclosures, motherboards/backpanels (mainly Scotland), network cards (Ireland only), low volume keyboards, media, kits, packaging material, and sub-assembly services. Furthermore, England and Wales figured to a small extent in the area of monitors while England played a role in the supply of motherboards as well. However, most of these components were imported from other regions as well. On average, ten per cent of the parts and components sourced by the focal companies in Ireland were manufactured in Ireland. The items manufactured in Britain were good for another four per cent on average. As regards the focal companies in Scotland, on average seven per cent of the material inputs was manufactured in Scotland while the items manufactured in the rest of Britain and Ireland made up another nine per cent.

As regards the material inputs manufactured in Ireland and Britain, the proximity of a number of suppliers turned out to be 'coincidental', i.e., not the result of a strong desire for buyer-supplier proximity. Where proximity was the result of a deliberate choice to deal with a supplier with a local manufacturing presence, logistical efficiency was the principal driver for proximity. Efficient technical information exchange proved an important proximity driver only in relation to packaging suppliers, although the driver played a modest role in relation to some other locally manufactured items.

In line with research pattern 2a, this was partly explained by the fact that the global business models of the focal companies did not require substantial regionally specific product development and the European operations did therefore not incorporate substantial local-for-local R&D groups. In relation to most components, the technical information exchange between the engineers of the European operations and the suppliers was relatively unintensive and a locally based representative of the suppliers could handle most communication.

Even if European operations had played a bigger role in the corporate process of technological co-ordination with suppliers, this would not have resulted in supplier co-location anyway. Information regarding the few cases of R&D activity carried out in European operations and regarding the corporate R&D groups shows that, even here, efficiency in technical information did not pose a strong driver for buyer-supplier proximity. A large part of the technical information exchange was unintensive and did not require face-to-face contact and in those cases where face-to-face communication was required, it posed no real driver for buyer-supplier co-location. It was relatively easy to organise this exchange, in an efficient way, with suppliers located further afield.

As regards logistics, the costs of holding inventories were well appreciated and the inbound inventories and pipelines were tightly managed. The picture is one of modest target buffer levels and high shipment frequencies. Most components manufactured in the Far East and the Americas involved target buffers of between eight and ten days and between weekly and bi-weekly shipments. Most material inputs manufactured in Europe involved target buffer levels of between eight and ten days and shipment frequencies of two or three times a week. As regards material inputs manufactured in the UK and Ireland, a number of items were manufactured on a true JIT or nearly true JIT basis, involving very low target buffer levels and daily or even more frequent shipments. Other components involved higher target buffer levels but shipment frequencies remained high – daily or every second day.

Although modest, these inbound target buffer levels were slightly higher than one would expect on the basis of comprehensive logistics management principles alone. However, these buffers did not reflect a sub-optimal supply chain solution, a reflection that would support rival research pattern 2b. The main reason for the slightly higher levels lay in the BTO production strategies of the microcomputer assemblers. A BTO production system with short order lead times in an environment of erratic final demand simply requires modest buffers between the suppliers and the manufacturing lines of the customer, except in situations of extremely short manufacturing cycles at the suppliers. In line with the target research pattern, the slightly higher target buffer levels were totally consistent with the comprehensive logistics management principles. In effect, the focal companies were simply trading-off the costs of modestly higher inbound inventories against the loss of market share and revenue due to stock-out.

In nearly all cases were the buffers positioned, as supplier-owned material, in local warehouses, local/regional manufacturing facilities of the suppliers or at turnkey supply-chain-managers. The warehouses were managed by 3pls (3pl hubs), the vendors (vendor hubs), or even the focal companies themselves. This local positioning of supplier-owned inventories should not be interpreted simply as a transfer of the burden of inventories from the focal companies to the suppliers – in line with rival research pattern 2b. Suppliers were compensated for the hubbing service and in many cases the focal companies had to take the material in the pipeline after a certain period, which meant that the risk of obsolescence was not entirely transferred to the supplier. Furthermore, even if the focal companies were not contractually obliged to take the product, they would not simply cut the pipeline off but work closely with the supplier to try and bring the inventories down.

The various component characteristics and contextual conditions that theoretically can affect the way companies manage their inbound logistics and the geography of the supply linkages proved relevant. In many cases these characteristics led to logistics systems that diverged substantially from the prototypical true JIT system. However, this should not be interpreted as support for rival research pattern 2b. In line with the target pattern, in all cases the divergences were totally consistent with the comprehensive logistics management principles. Regional differences in labour costs had a particularly strong effect on the geography of the production linkages. To attain total supply chain cost effectiveness, companies balanced the efficiencies in logistics gained by using local suppliers against material cost price advantages gained by using suppliers in low-wage regions. In many cases the optimal solution involved suppliers located in the Far East.

CHAPTER 6 CONCLUSIONS

This concluding chapter is divided into four sections. The first section discusses the contributions of this dissertation to the literature. The main limitations of the research are outlined in section 6.2. This is followed by a discussion of the implications for industrial development policy in section 6.3. The final section presents suggestions for further research.

6.1 Contribution to the Literature

This research has contributed to and developed the literature in a number of ways. Firstly, the theoretical underpinnings of the concept of NHVP have been developed by positioning NHVP as a distinct post-Fordist form of industrial organisation and describing its generic elements. Initially the literature on the perceived transition from a Fordist form of industrial organisation to a post-Fordist form focussed on the idea of flexibly specialised conglomerations of co-operating SMEs, involved in craft production, as the dominant form (Piore and Sabel, 1984). These early ideas were quickly watered down by the introduction of the possibility of flexible specialisation around large firms (Sabel, 1994, p. 145; Scott, 1992). However, a growing body of academics recognises the rise of a different form, referred to by Hudson as New High Volume Production (NHVP) approaches (Hudson, 1995; Hudson, 1997a; Hudson, 1997b; Hudson, 1997c; Hudson and Schamp, 1995).

Although the existence of NHVP approaches has been acknowledged for some time, this dissertation positioned them more precisely amid the other post-Fordist forms of industrial organisation by identifying the divergences as well as the commonalties. Furthermore, based on a detailed comparison of four text-book NHVP models – JIT/TQM (Sayer, 1986); Lean Production/ Lean Supply (Lamming, 1993; Womack, Jones, and Roos, 1990); Mass Customisation (Pine, 1993); Time-Based-Competition

(Stalk and Hout, 1990) – this dissertation more precisely identified the generic elements of NHVP approaches and, importantly, the way these are related.

It was shown that, in contrast to flexible specialisation, NHVP still incorporates strong elements of mass production. All NHVP firms, in one way or another, "combine the benefits of economies of scope and greater flexibility in responding to consumer demand which are characteristic of small batch production with those of economies of scale, characteristic of mass production" (Hudson, 1997b, p. 303). Economies of scale continue to matter in many situations. Therefore, in contrast to flexibly specialised conglomerates of SMEs, NHVP involves large establishment sizes. In this respect NHVP is similar to the model of flexible specialisation around large firms. However, where flexible specialists focus on the production of small batches of extremely varied products which may go through many design changes as they are in process, NHVP approaches still involve a high degree of standardisation and routinisation. The degree of product differentiation is lower. Furthermore, whereas flexibly specialist production units consume a wide range of diverse, variable and often unpredictable inputs, NHVP approaches still involve a high degree of component standardisation and streamlining of inputs.

As regards the industrial organisation, like flexible specialisation around large firms, NHVP involves a high degree of vertical disintegration in combination with strong customer-supplier co-operation. However, whereas the large flexible specialist producers deal directly with a large number of constantly changing small specialised suppliers, the NHVP companies, in search of economies of scale in component production and efficiency in the co-ordination of the supply chain, aim to rationalise and stabilise their supplier base. Therefore, compared to the flexible specialisation model, the idea of NHVP approaches involves a significantly smaller supplier base and a higher degree of vertical inter-firm organisation and hierarchy.

Secondly, building further on the clearer conceptualisation of NHVP, the research contributes to the literature by identifying the drivers for possible buyer-supplier proximity in NHVP industries located in non-core regions. It was shown that, as in the case of flexibly specialised conglomerations of SMEs, buyer-supplier proximity in NHVP industries might be driven by a search for efficiency in product flow/logistics and information flow. However, as regards information flow, the logic in relation to NHVP industries is narrower than the logic in relation to flexibly specialised conglomerations of SMEs. In the first case the logic is that proximity will enhance the efficiency in the formal exchange of information between partners, in the context of increased functional integration. The logic cannot be that spatial proximity will increase the transaction cost efficiency in the context of increased information linkages spawned by processes of vertical disintegration, as put forward by some of the proponents of the flexible specialisation thesis (e.g., Scott, 1988). The strongly rationalised and relatively stable supply chains make this logic irrelevant in the context of NHVP industries. Socio-cultural and institutional factors enhancing information flow between actors in a local milieu are generally not considered as proximity drivers in NHVP industries, especially not in the context of non-core regions. However, following Cooke and Morgan (1998) it was pointed out that it is at least theoretically possible that once a grouping of NHVP branch-plants has developed on the basis of efficiency factors, socio-cultural and institutional factors start to play a bigger role.

The main contributions to the literature are made by addressing the central problem statement of the dissertation:

> *Do NHVP approaches have significant indirect development effects in the form of linkages, in non-core regions? How does NHVP affect the geography of production linkages?*

With the first part of the problem statement – *Do NHVP approaches have significant indirect development effects in the form of linkages, in non-core regions?* – the research aimed to contribute detailed information regarding the amount of backward linkages generated by NHVP plants in non-core regions. The question was also aimed at gaining a strong and unambiguous basis for answering the second problem statement. With the second part of the problem statement – *How does NHVP affect the geography of production linkages?* – the research aimed to test and advance existing theories regarding the drivers behind the geographical configuration of supply chains.

Based on a critical analysis of the logic related to buyer-supplier proximity drivers relevant to NHVP industries one target research pattern and three rival research patterns were formulated to guide the research. The research investigated the role of the two buyer-supplier proximity drivers that are most often put forward in relation to NHVP industries: efficient product flow/logistics and efficient formal information exchange in the context of inter-firm functional integration. With this focus, the research did not incorporate the role of socio-cultural and institutional issues in driving buyer-supplier proximity although it is acknowledged that the issues might be relevant.

The relevance of the various research patterns was tested in a case study of the microcomputer hardware industry in Ireland and Scotland, an industry that has been presented as a good example of NHVP (Hudson, 1997c; Kotha, 1995, International Business Week, 03-10-1983 and 14-05-1984; Morgan, 1991; Sayer, 1986). As outlined in the conclusion of Chapter 5, the situation in the microcomputer industry in Ireland and Scotland matches closely the target research pattern 2b: no significant local linkages – neither comprehensive logistics management principles nor technical information exchange drive proximity, but the principles are appreciated. The findings provide very limited support for the three rival research patterns.

The findings have a number of implications for existing theory. There are literatures that suggest that the adoption of NHVP approaches will have positive implications for regional development of non-core regions because of greater indirect, backward linkage, effects (Estall, 1985; Kenney and Florida, 1992; Mair, Florida, and Kenney, 1988). The idea that NHVP approaches will lead to an increase in local production linkages is generally based on a relatively straightforward spatial proximity argument. The argument generally involves two proximity drivers: efficient product flow or logistical efficiency and efficient formal technical information exchange in the context of increased inter-firm functional integration.

Existing empirical evidence regarding the extent of local linkage formation in sectors and companies that are generally associated with NHVP is partly in support and partly in conflict with this positive scenario. In the context of peripheral regions in Europe the positive expectations have been supported by a number of case-studies or surveys that found that NHVP industries or companies sourced a higher percentage of their material inputs from the local economy than other industries or companies (McCann, 1998; McCann and Fingleton, 1996; Phelps, 1997) or that they were increasing their linkages with the local economy (Cooke, 1995; Jones and North, 1991; Morris, 1992; Morris, Munday, and Wilkinson, 1993; Munday, Morris, and Wilkinson, 1995; Phelps, 1993a; Phelps, 1993b; Sadler, 1997). On the other hand, many of these studies (Morris et al., 1993; Munday et al., 1995; Phelps, 1993a; Turok, 1993; Phelps, 1993b; Turok, 1997) as well as other studies (Bordenave and Lung, 1996; Clarke and Beany, 1993; Hudson, 1997a; Pike, 1998; Schamp, 1991) showed that the level of local sourcing remains low.

This case study of the microcomputer hardware industry, and this is the third contribution to the literature, extends the empirical evidence regarding the extent of local linkage formation in NHVP sectors in non-core regions. The detailed examination of the supply chains in Chapter 5 showed that the 11 focal companies were supported by over 109 regional suppliers operating 125 plants. The findings might suggest some kind of an agglomeration effect in that the majority of plants were supplying two to three focal companies.

However, local linkage formation by subsidiaries of microcomputer assemblers in Ireland and Scotland remained relatively limited. The vast majority of components and parts were imported from regions outside Ireland and Britain, notably from the Far East and, to a lesser extent, the USA. Furthermore, it was shown that the actual production activities carried out by suppliers located in Ireland or Scotland were very limited or added limited value to the product. Thus, the findings of this research do not support the positive scenario suggested by some of the studies outlined above. These findings are very similar to those of Angel and Engstrom (1995) in their study of the PC industry in the USA. Here too, the vast majority of components and parts was imported from the Far East. The only items that were mainly sourced from local suppliers included metal casings, screws, labels and so forth.

The fourth contribution to the literature concerns the role of the first theoretical driver for buyer-supplier proximity – efficient formal technical information exchange – in shaping the geographical configuration of backward linkages in NHVP industries. Textbook NHVP models are characterised by strong customer-supplier integration, involving a great deal of technical information exchange between buyers and their suppliers. There are those who argue that this will lead to buyer-supplier proximity since a large part of the exchange requires face-to-face interaction between engineers (Reid, 1995; Schoenberger, 1997). Others have argued that innovations in communication technology have reduced the need for face-to-face contact, even in the context of detailed technical design issues (Gertler, 1988; Hepworth, 1989; McKinnon, 1997). The findings of the case study of the microcomputer hardware industry in Ireland and Scotland provide more support for the latter group of authors. Efficiency in technical information exchange was a relatively insignificant driver for buyer-supplier proximity.

The research shows that the role of technical information exchange as a driver for proximity is partly dependent on the detail of the corporate organisation and the functions bestowed on subsidiaries. The textbook NHVP system of multiregional production involves 'top-to-bottom', 'paper-concept-to-finished-product', manufacturing systems in each of the main markets of the world (Womack et al., 1990). In contrast, and partly in support of the more sceptical stance adopted by Hudson (1994), in the microcomputer industry R&D remained strongly centralised in the home countries of the focal companies. The global business models of the focal companies did not require substantial regionally specific product development and the European operations therefore did not incorporate substantial local-for-local R&D groups. As a result, with respect to most components, European operations had a very limited involvement in technological co-ordination with suppliers. The non-intensive nature of the technical information exchange between the engineers of the European operations and their suppliers represented only a weak driver for buyer-supplier co-location.

Furthermore, the research provides further support for Arita and McCann's (2000) findings that only technical information exchange with a high intensity will drive buyer-supplier proximity. In Chapter 5 it was shown that, even if European operations of the focal companies had played a bigger role in the corporate process of technological co-ordination with suppliers, this would not have resulted in supplier co-location. Information regarding the corporate R&D groups, mainly located in the USA, shows that even here efficiency in technical information did not lead to buyer-supplier proximity. Similar results have been reported by Angel and Engstrom (1995) in their study of the PC industry in the USA. Angel and Engstrom explain the limited buyer-supplier proximity by the fact that the industry has developed many characteristics of a modular system (Langlois and Robertson, 1995). In such a system the need for co-ordinated technology development is reduced and, the argument flows, this reduces the role of technical information exchange in driving proximity.

The results of the present case study point to a slightly different explanation. Although the ideas of Langlois and Robertson were partly supported by the findings of the present study, the situation was not as extreme. The innovation process still involved a substantial amount of co-ordination and information exchange between the focal companies and the component suppliers. Following Arita and McCann, this research suggests that the explanation for the fact that this technical information exchange did not lead to buyer-supplier proximity lies in the intensity of the technical information exchange involved, i.e. the detail and sensitivity of the information exchanged. Most partnerships in the microcomputer industry are lower-order alliances characterised by technical information exchange of a low intensity. This technical information exchange requires low levels of face-to-face contact and therefore presents a weak driver for proximity.

The fifth contribution to the literature concerns the role of the second theoretical driver for buyer-supplier proximity – logistical efficiency – in shaping the geographical configuration of backward linkages in NHVP industries. Textbook NHVP models are characterised by the pursuit of optimally efficient inbound logistics systems. True JIT supply, characterised by a virtual elimination of buffer inventories and a *kan-ban* delivery system that delivers inputs on a daily basis, is often presented as the optimal system and some geographers suggest that it will lead to close buyer-supplier proximity (Estall, 1985; Kenney and Florida, 1992; Mair, 1992; Mair et al., 1988; Sayer, 1986; Schoenberger, 1997). Others argue that developments in transport and logistics render the proximity argument obsolete for all but a few exceptional situations (Lamming, 1993; Milne, 1990). The findings of the case study of the microcomputer industry in Ireland and Scotland provide most support for the second idea, but the situation is more complex.

This research shows that true JIT supply should really be interpreted as one extreme outcome in a spectrum of possible optimal outcomes based on modern comprehensive logistics management principles, which take account of the interrelationships between inventory costs, transportation costs, shipment frequencies, the opportunity costs of quality associated with inventory and variation in labour costs between regions. A number of component characteristics and contextual conditions can lead to supply systems involving less frequent delivery patterns, greater shipment sizes, higher buffer levels and longer buyer-supplier distance.

In the microcomputer industry in Ireland and Scotland a small number of items were supplied on a true JIT basis by manufacturers located in close proximity. However, the vast majority of material inputs were imported from other regions, notably from the Far East. The supply chains generally involved inbound inventories, stored in local warehouses from where the manufacturing lines were supplied on a very frequent basis. In relation to this, for the first time this research provided a detailed account of a new and innovative way of structuring inbound logistics pipelines – hubbing.

Such logistics systems have been referred to as 'apparent JIT' (Lamming, 1993; Ryan, 1997) or 'pseudo JIT' (Hudson, 1994) and it has been suggested that they are sub-optimal and hold no benefit for the supply chain as a whole, since the costs of inventory remain in the system (Lamming, 1993). This research showed that the logistics systems of the focal companies in the microcomputer industry were not sub-optimal. By sourcing from the Far East, companies were simply trading-off price advantages gained by using suppliers in low-wage regions against the efficiencies in logistics gained by using local suppliers, totally consistent with the modern comprehensive logistics management principles. Growing regional differences in labour costs in combination with innovations and price reductions in transport and logistics meant that the optimal solution involved suppliers in the Far East. Similarly, the effects of various component characteristics, such as unit value, bulkiness, minimum efficient scale of production and variety of options were consistent with what could be expected on the basis of the comprehensive logistics management principles. The necessary inbound inventories were tightly managed. The detailed account of the logistics data in Chapter 5 paints a picture of modest target buffer levels and high shipment frequencies.

The inbound buffer levels were slightly higher than one would expect on the basis of comprehensive logistics management principles alone. However, this research was able to show that this was not indicative of a sub-optimal supply chain solution. Rather, the main reason for the slightly higher levels lay in the BTO production strategies of the focal companies – underlining the value of taking account of the interrelationships between the various elements of the value chain when analysing the geographical configuration of backward linkages.

After these main contributions, the sixth and final contribution to the literature is an assessment, in a more dynamic framework, of the indirect effects of NHVP-adopting MNEs in non-core regions, i.e. an assessment of the actual impact of the linkages on the quality and competitiveness of the regional supplier base. As mentioned in section 2.4.2, it has been suggested that the quality of the supply chain relations of MNEs that adopt NHVP approaches will have a positive effect on regional industrial capability and competitiveness, particularly in peripheral and semi-peripheral regions (Munday et al., 1995). According to this view suppliers are accorded increased technical roles and supply-relationships are long-term and co-operative rather than adversarial. The closer contact between customer and supplier will increase the demonstration effect of the core companies, leading to a general upgrading of the local supplier base and increased technological spin-offs. Other geographers paint a less positive picture. Hudson (1997c), for example, believes that the supply chain relations will retain many Fordist characteristics and remain of a dependent nature.

This research shows that NHVP-adopting MNEs can indeed have a significant dynamic effect on their local suppliers in non-core regions. The MNE customers in the microcomputer industry have had a significant positive impact on the quality and competitiveness of nearly all local suppliers they were dealing with. Contact with the MNE customers and the supplier development efforts of the MNEs led to a significant upgrading of the local suppliers in various areas. This up-grading facilitated the internationalisation of a number of the indigenous companies. The problem was that the MNEs had relatively few local linkages, which limited the overall impact on the regional industrial capability and in many cases the linkages involved subsidiaries of other MNEs.

It is not easy to relate these findings back to the more general typologies of MNEs and their subsidiaries as brought up in the introduction of Chapter 2. There it was mentioned that some authors contrast the 'cost or price sensitive company' with the 'performance company' with its 'performance' or 'quality plants' (Amin, Bradley, Howells, Tomaney, and Gentle, 1994; Amin and Tomaney, 1995; Hardy, 1998; Pike, 1998). Others apply concepts such as the 'developmental multinational subsidiary' (Young, Hood, and Peters, 1994) or 'technical branch-plants' (Glasmeier, 1988) while Turok (1993) juxtaposes 'developmental' and 'dependent' linkage scenarios. As regards the indirect regional development effects, based on the limited amount of linkages created, the focal plants in the microcomputer hardware industry cannot be considered performance plants with a developmental linkage scenario. However, the local linkages that the focal companies created had all the characteristics of developmental linkages – again, the problem was that, due to contextual and component characteristics, the focal companies had created relatively few such linkages. This brings into question the value of these rather broad typologies.

Furthermore, it should not be forgotten that the focal companies might well have had a substantial regional development effect via another route. Although outside the scope of this dissertation, the interviews did touch issues related to the direct development effects of the focal companies, notably employment structure, training efforts and functions of the local operations. The incomplete data suggest that the subsidiaries in the microcomputer industry might have characteristics that fit the concept of performance company as well as characteristics that fit the cost or price sensitive company. Thus, the already mentioned limited R&D functions of the local operations would fit the concept of the cost sensitive company as would the industrial relations practices, with almost none of the companies recognising trade unions. On the other hand, the focal companies do have characteristics of the performance company. Thus, apart from simple assembly functions, nearly all local operations were performing a range of other functions, notably sales and technical support, logistics and, in some cases, shared HQ functions. Employment figures reveal that, apart from high numbers of low skilled labour, the companies employed large numbers of highly skilled technicians/engineers as well as managerial, supervisory and professional workers. Finally, all focal companies were spending great resources on the training of their workforce.

Having discussed the main contributions of the research regarding the geography of production linkages in the microcomputer industry, questions arise regarding the overall geography of the industry. The fact remains that at the time the research started, in 1998, both Ireland and Scotland had a sizeable grouping of microcomputer assemblers. The most important branded computer makers with manufacturing facilities in Europe were concentrated in Ireland and Scotland and together these companies produced the bulk of branded microcomputers sold in Europe. The grouping suggests that agglomerative forces were in operation. The findings of this research suggest that, if the concentration was the result of agglomerative forces, it is unlikely that these were related to buyer-supplier product flow or information exchange. So what other factors might have underlain this concentration of microcomputer assemblers?

First, the concentration of assemblers might be related to the agglomeration advantages in the form of a local pool of labour, providing efficiency gains by maximising job-matching opportunities (Gordon and McCann, 2000; Krugman, 1991). Second, there is the possibility that part of the explanation for the concentration of assemblers lies in socio-cultural and institutional factors, but here not related to local buyer-supplier linkages. Apart from enhancing buyer-supplier relations, socio-cultural and institutional assets and an associational capacity can facilitate a co-ordinated approach towards inward investment promotion, industrial policy, enterprise support and the provision of education and training, and this co-ordinated approach might have been instrumental in the companies' decision to invest or expand in Ireland or Scotland. Finally, there is always the possibility that there are no agglomerative forces at play and that the location of individual assemblers is largely unrelated to the presence of the bigger group of assemblers. It might well be that the concentration of assemblers is largely driven by the simple fact that all assemblers are attracted to a location offering a ready supply of relatively cheap and skilled labour, fiscal and financial incentives and access to the European market.

6.2 Limitations of the Study

As regards the limitations of the study, the first thing that needs to be stressed is that the main findings of the case study, those directly related to the problem statement outlined above, cannot be generalised to the wider population of NHVP industries. As explained in Chapter 3, the case study design does not involve a generalisation to populations. Rather, theories about the geographical configuration of other NHVP industries are the target to which the results might be generalised. However, this generalisation is not automatic but requires the replication of the findings in a second or even third NHVP industry. Thus, the present case study serves as one element in a broader academic process of cumulative theory formation in which future case studies will further support, refine or adapt the developed target theory. The most obvious industries for future case studies are outlined in section 6.4.

The second limitation of the study is of a methodological nature and might affect the validity of the conclusions. No precise data were collected on the inventory levels at suppliers' manufacturing facilities in other continents. It is therefore theoretically possible that the supply pipelines of the focal companies involved substantial inventories at the suppliers' manufacturing facilities in the Far East and the Americas, making the logistics systems less efficient than the key logistics data presented in this dissertation would suggest. However, based on logically deduced ideas as to the production and logistics systems at suppliers in other continents as presented in Chapter 5, the (informed) suppositions of interviewees and the feedback from academics, my contention is that this is unlikely, to be the case.

The third limitation is that, in search for an explanation of the geography of production linkages, the research only investigated the role of the two buyer-supplier proximity drivers that are most often put forward in relation to NHVP industries: efficient product flow/logistics and efficient formal information exchange in the context of inter-firm functional integration. The role of socio-cultural and institutional issues in driving buyer-supplier proximity was outside the focus of this research. Although these issues are seldom brought up as a driver for buyer-supplier proximity in the context of subsidiaries of NHVP industries in non-core regions, as mentioned above, it is theoretically possible that these issues have been partly responsible for the local linkages created by the microcomputer companies in Ireland and Scotland. The precise role of these issues can only be established by additional research. However, given the fact that the focal companies created few local linkages, one can already draw the conclusion that they were not a strong buyer-supplier proximity driver in case of most components.

6.3 Implications for Industrial Development Policy

If the conclusions of this research are valid than the findings hold lessons for industrial development policy in Ireland and Scotland. Industrial policy and the strategies of the industrial development agencies in Ireland and Scotland have long included the idea of building integrated vertical production clusters around subsidiaries of MNEs (IPRG, 1992; Turok, 1997). The findings of this research suggest that such a strategy is becoming increasingly unsuitable in the context of most NHVP industries, although it might partly depend on the physical characteristics of the components used. The growing difference in labour costs between Ireland/Scotland and the Far East and recently Eastern Europe, in combination with innovations and price reductions in transport and logistics make it increasingly unlikely that such policies and strategies will be met with success if applied to the microcomputer hardware industry. In fact this research showed that, since the mid-1990s, a substantial number of suppliers of the microcomputer assemblers downsized or closed their manufacturing operations in Ireland or Scotland. The present supply-chain solutions diverge from the prototypical true-JIT systems. However, one should not expect a development in the direction of true JIT and an associated increase in local sourcing. The logistics systems in the microcomputer industry simply present the optimal supply-chain solution in the present context.

The strategy of building integrated vertical clusters around subsidiaries of MNEs involved in NHVP is probably increasingly unsuitable in the context of most other NHVP industries as well. The strategy might meet more success in industries using components with a high physical volume or weight. The strategy might also be more suitable in industries where partnerships involve higher-order alliances, such as joint R&D, characterised by technical information exchange of a high intensity, although even here the success of the strategy is conditional on the global business models requiring substantial regionally specific product development, carried out by local for local R&D groups.

The unsuitability of a strategy of building and maintaining fully integrated vertical clusters around the subsidiaries of microcomputer assembly companies has been recognised to some extent by the industrial development agencies, at least in Ireland. The idea of building an integrated PC cluster was still very much part of the IDA strategy in 1995 (Casey, 1995). But one year later, in response to the increasing competitive pressure from low cost locations in the second half of the 1990s, the IDA started to actively discourage companies from establishing certain manufacturing operations in Ireland where the main attraction was a lower cost base (Carey, 1996), and in its 1996 review the sub-sector 'peripherals and media' was dropped as a key target sector for promoting foreign direct investment.

This does not mean that the strategy was initially incorrect. The strategy was probably the correct one in the context of semi-peripheral Ireland/Scotland during the 1980s and early 1990s and is currently probably still the correct one for other peripheral and semi-peripheral economies, notably China, Indonesia, Malaysia and some Eastern European economies. During the 1980s and early 1990s the difference between wage levels in Ireland/Scotland and those in relevant countries in the Far East was far smaller than it is now and Ireland and Scotland could still successfully compete for low-wage based manufacturing operations. Over the period, both countries attracted a certain number of component manufacturers that, apart from providing welcome employment opportunities for lower skilled labourers, also employed and trained an increasing number of engineers, technicians, managers and other professionals, thereby upgrading the quality of the workforce for a next generation of inward investments. Furthermore, the expanded supply-base, although relatively limited, was probably a helpful factor in persuading other assembly companies to invest in Ireland/Scotland.

The point is that during the 1990s both Ireland and Scotland appear to have started a transformation from semi-peripheral economies to high-wage core economies. In such a context a strategy of building fully integrated vertical manufacturing clusters around subsidiaries of microcomputer assemblers and many other NHVP companies appears unsuitable. Microcomputer assemblers will continue to create a certain amount of backward linkages with the local economy, but these will increasingly be of a service type, as in turnkey supply-chain-managers and logistics providers, rather than of the manufacturing type.

Anyway, the suitability of a strategy of building integrated clusters around subsidiaries of MNEs involved in NHVP might well become an academic issue. The above mentioned growing difference in labour costs between Ireland/Scotland and the Far East and recently Eastern Europe and the innovations and price reductions in transport and logistics not only reduce the relative attractiveness of Ireland and the UK as a location for microcomputer component production. Even more threatening, it also appears to reduce their attractiveness as a base for system assembly.

Some argue that shipping costs basically rule out the importation of computer systems from South-East Asia to Europe (Mulqueen, 2000). However, recent shifts of system assembly activity out of Ireland and the UK suggest that this is not necessarily so. One case is Apple that in 1999 first subcontracted the assembly of the I-Mac to LG in Wales. This proved not to be cost-efficient and production was shifted to the Far East (Interview Barry, Apple, April 2001). More recently Packard Bell-NEC was planning to close its Scottish manufacturing plant and shift the production of microcomputers for the European market to China (Lerner, 2002). In a similar way, companies have been shifting production to Eastern Europe. For example, in 2001 Compaq in Scotland out-sourced a large part of PC assembly activities to a supplier in the Czech Republic (Grande, 2001) while in 2000, Apple shifted the I-Mac business to a new partner with manufacturing facilities in the Czech Republic.

These shifts of assembly activity to low-cost locations in combination with a competition induced shake-out of branded microcomputer makers have led to a serious reduction in microcomputer assembly activity in Ireland. Thus, of the five original focal companies in Ireland, by 2002 only Dell and Apple were still assembling microcomputers while Apple's assembly operations were seriously downsized compared to 1998. Similarly, of the six original focal companies in Scotland, only Sun, Packard Bell-NEC, IBM and

Compaq were still assembling systems by 2002. Furthermore, IBM and Compaq had significantly downsized their assembly operations while Packard Bell-NEC was planning to close its plant.

Clearly a strategy of building integrated vertical clusters around manufacturing subsidiaries of MNEs involved in NHVP does not look very promising in the context of Ireland and Scotland. Young et al. (1994, p. 669) call this the "local sourcing route" to cluster development around subsidiaries of MNEs. The alternative route identified by the authors is via "technological innovation". Here, technological cluster development might be stimulated through co-operative R&D projects involving companies, university research labs and government research institutions. This appears to be the more appropriate route for Ireland and Scotland to take but it is difficult to see how NHVP operations can play a role where these operations do not incorporate substantial local-for-local R&D groups, as is the case in the microcomputer hardware industry.

6.4 Suggestions for Further Research

The discussion of the contributions and limitations of this research provide several leads to further research. First, as mentioned in section 6.2, the present case study serves as one element in a broader academic process of cumulative theory formation in which future case studies will have to further support, refine or adapt the developed target theory.

The most obvious contenders for replication case studies in the context of Ireland and Scotland would be the telecommunication and networking hardware industries that appear to have many characteristics of NHVP industries. Furthermore, in the context of other UK non-core regions the consumer electronics and automobile industries are obvious examples of NHVP industries. This latter industry can also serve as a critical case for the further testing of one part of the theory – the idea that the causal relation between logistical efficiency and customer-supplier proximity is partly dependent on the bulkiness of the supplied components. Most of the components used by the microcomputer hardware industry have a relatively low physical volume and the findings confirmed the postulation that this characteristic is one of the factors influencing the linkage distance. Many of the components in the automobile industry have a high physical volume, which makes the industry a critical case for the further testing of the effect of this component characteristic.

Secondly, to complement the present research, future studies might focus more on the role of socio-cultural and institutional issues in driving buyer-supplier proximity. These issues were not touched in the present research because they are seldom brought up as a driver for buyer-supplier proximity in the context of subsidiaries of NHVP industries in non-core regions. However, it is theoretically possible that these issues did play a role.

Thirdly, one of the limitations of this research was that no precise data were collected on the inventory levels at suppliers' manufacturing facilities in other continents. An investigation into the production systems and outbound inventory levels at suppliers' manufacturing facilities in South-East Asia and the Americas might confirm the logically deduced ideas and suppositions of the interviewees, thereby increasing the robustness of the developed theory.

Fourthly, this research established that buyer-supplier linkage related factors probably only played a very limited role in the formation of the existing grouping of microcomputer assemblers in Ireland and Scotland. It would be very interesting, from both an academic and policy perspective, to establish in future research what has driven this concentration of microcomputer assemblers, or indeed other concentrations of NHVP companies in Ireland and Scotland.

Finally, the present research found indications of a possible shift of both component manufacturing and system assembly activity in the direction of Eastern Europe, notably to the Czech Republic and Hungary. Some activity is relocating from Ireland/Scotland while other activity appears to be shifting back from the Far East to Europe, consistent with the comprehensive logistics management principles. A detailed investigation of this shift of MNE manufacturing and assembly activity out of Ireland/Scotland along with an analysis of the kind of activities that are retained would make an important contribution to the academic and policy debate on industrial development

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Interviews With Focal Companies

Apple Computers, Cork, Ireland

Ms Abbott, Sara	HR Manager	September 1999
Mr Barry, John	Logistics Manager	December 2000, April 2001
Mr Gantley, Joe	Managing Director and Director EMEA	October 1999
Mr Ruddy, Ciaran	Material Manager	September 1999, October 1999
Ms Walsh, Hellen	Materials Manager	November 1998

Apricot-Mitsubishi, Glenrothes, Scotland

Mr Campbell, Bill	Managing Director	July 1999
Mr Carson, Kevin	Materials and Procurement Director	February 1999, July 1999, April 2001

AST Research, Limerick, Ireland

Mr Cahalane, Joe	Managing Director (acting)	September 1999
Ms, Clarck, Ann	HR Manager	September 1999
Ms Kiely, Caroline	Materials Manager	November 1998
Mr Frawley Neil	Materials Director	November 1998

Compaq Computer Manufacturing, Bishopton, Scotland

Cameron, David	HR Manager	September 1999
Darragh, Jim	Material Manager	September 1999, April 2001
Hedry, Agnes	HR Officer	September 1999
MacIntyre, Alan	Purchasing Manager	February 1999, September 1999
Mcnair, Ian	Site Director	February 1999, September 1999

Dell Computer Corporation, Limerick, Ireland

Mr Allen, Padraigh	Vice President Manufacturing	October 1999
Mr Casey, Pat	HR Manager	
Mr Clarke, Gerry	Strategic Project Manager	October 1999
Mr Hennesey, Ray	Logistics Manager (Outbound)	October 1999
Mr Lucey, Denis	Director European Product Group	January 2000
Mr O'Donnal, Dan	Logistics Officer (Inbound)	October 1999, April 2001
Mr Walsh, Mike	Materials Officer	November 1998, October 1999, April 2001

Digital Equipment Corporation, Ayr, Scotland		
Ms. Auld, Yvonne	HR Manager	July 1999
Mr. Cairns, Bernie	Planning and Procurement Manager	July 1999; April 2001
Mr. Hammond, John	Training Manager	July 1999
Mr. Tyldsley, Gary	Commodity Manager	Feb 1999; July 1999
Gateway Computers, Dublin, Ireland		
Mr. Flynn, Dave	Operations and Production Manager.	November 1998; September 1999; January 2000; April 2001
Mr. Hammil, Don	HR Manager	November 1999
Ms. Kelly, Linda	Procurement Officer	November 1998
Mr. Maloney, Mike	Site Manager and Director of Marketing EMEA	November 1999
Ms. Yazdampen, Tanya	Training Manager	November 1999
IBM UK, Greenock, Scotland		
Mr. Baillie, Ian	Distribution and Logistics Manager	February 1999
Mr. Harley, Michael	HR Manager	July 1999
Mr. Higgy, Bob	Director of Development	July 1999
Mr. Nugent, John	Manager Operational Input Technologies	February 1999 July 1999
Mr. Stanton, Harry	Procurement Manager	February 1999; July 1999; April 2001
Intel Ireland, Leixlip, Ireland		
Mr. Nagle, Liam	Former Manager ESSM Systems Division	November 1998; March 1999
Ms. O'Farrel, Una	Procurement Officer, Intel Cartridge Plant,	April 1998
Mr. Smith, Nick	Procurement Officer, Intel Fab. 10 and 14	July, 1998
Packard Bell-NEC, Livingston, Scotland		
Mr. Allen, Tony	Managing Director	April 2001
Mr. Bucannon, David	Technical Trainer	September 1999
Ms. Collins Caroline	HR Manager	October 1999
Mr. Loocker Paul	Managing Director	October 1999
Mr. Rooney Barry	Materials Manager	September 1999 October 1999

Sun Microsystems, Linlithgow, Scotland		
Mr. Aitken, Hugh	Vice President European Operations	August, 1999
Mr. Bain, Colm	European Systems Manager	February 1999; July 1999
Mr. Carslow, Alison	HR and Training Officer	July 1999
Mr. Kerr, Eddie	Supply Materials Director	July 1999
Mr. Steven, Graham	Logistics Director	May 2001

Telephonic Interviews with a Selection of Supplier Firms

Alps Electronic, Millstreet, Ireland		
Mr. O'Shauglin, Brendan	Production Manager	February 2001
Amphenol, Port Glasgow, Scotland		
Ms. Meers	Information Officer	February 2001
B.G Turnkey Services, Cork, Ireland		
Mr Doyle, Brian	Sales Division Manager	February 2001
Foxteq Engineering, Mullingar, Ireland		
Ms. McCann, Emelda	Production Material Control Manager	April 2001
LMS-Beach (Flextronics Enclosures), Tullamore, Ireland		
Mr. Roche, Sean	Logistics Manager	April 2001
Logitech, Cork, Ireland		
Information Officer	Information Officer	February 2001
Methode Ireland		
Mr. Ryan, Kieran	Technical Sales Engineer	February 2001
Modus Media, Kildare, Ireland		
Mr. Fisher, Stephen	General Manager	February 2001
Mr. Coldwell, John	Sales Director	February 2001
NABS, Greenock, Scotland		
Sales Officer	Sales Officer	February 2001
Phoenix Cables, Irvine Scotland		
Sales Officer	Sales Officer	February 2001
Quantum, Dundalk, Ireland		
Mr. Murphy, Leo	Production Manager	April 2001
SerCom Solutions (Printech), Dublin, Ireland		
Mr. O'Grady	Marketing Manager	February 2001

Sykes (SDL International), Galashiels, Scotland

Mr. Madden, Mike	Operations Manager	February 2001

Techdyne, Livingston, Scotland

Mr. Patterson, David	Operations Manager	February 2001

US Print, Livingston, Scotland

Ms. Meek, Beverly	Information Officer	February 2001

Volex, Calstelbar, Ireland

Production Manager	Production Manager	February 2001

Interviews with Industrial Development Organisations

Scottish Enterprise, Glasgow, Scotland

Mr. Bryce, Alex	Manager, Information Industries Group (Locate in Scotland)	December 1998
Mr. Togneri, Martin	Senior Director International Operations (Scottish Development International)	December 2001

IDA Ireland, Dublin, Ireland

Mr. Hanna, David	Manager ICT Division	December 2001
Mr. Murphy, Donal	ICT Division East Coast/Mid-West USA & Asia	April 1998

Forbairt, Dublin, Ireland

Kennedy, Tom Kennedy	Project Manager National Linkage Programme	October 1996

Interviews with Other Informants on Development of Computer Industry in General

Adamson, Jim	Former Managing Director, NCR, Scotland	December 2001
Frane, Tom	Former Managing Director Honeywell, Scotland,	December 2001

APPENDIX A LETTERS SENT TO FOCAL COMPANIES

A 1 Letter of Introduction

Mr /Ms X
Managing Director
Company X

Dublin, October 1st 1998

Re Participation in research Dublin City University/ IDA-Ireland.

Dear Mr /Ms X

Thank you very much for co-operating in our project You asked me to provide some further detail about the research project and the kind of information we are looking for

As you already know the project is funded by Forfas and has the backing of IDA Ireland They hope that the study will provide them with a better understanding of the geographical aspects and infrastructural requirements of new high volume production concepts, e g Mass Customisation We identified Company X as a good example We will study the spatial implications and logistical requirements of new high volume production concepts with a focus on supply-chain relations

We are developing a rather comprehensive research design Given the complexity of the topic we think it will eventually be necessary to talk to different people in your company However, before finalising a detailed design, we aim to collect part of the data we are interested in This will help us to fine-tune the second part of the data-collection stage In this first stage we would like to discuss your supplier relations in a short (not more than one hour) interview We aim to get insight into the geographical location of your suppliers and inbound logistical arrangements We are not searching for figures of any kind! The materials manager might be the most suitable member of your management team

Building on the acquired insights, we will subsequently prepare a second questionnaire, which will explore the requirements of Time-Based-Competition in more detail This next phase of research is scheduled for the second quarter of 1999 We will contact you again in order to discuss the most appropriate member of staff for interview

Yours sincerely,

Drs Chris van Egeraat
Dublin City University Business School
Economics and Finance Group, Tel 01-8681729

A 2 Invitation to Participate in Second Stage of Research

Mr /Ms X
Managing Director
Company X

Dublin, July 21st 1999

Re Participation in second stage of research Dublin City University Business School/ IDA-Ireland

Dear Mr /Ms X

As you already know, Dublin City University Business School, in co-operation with IDA-Ireland, is undertaking research on the relation between new production concepts and the spatial structures of production networks and the implications for industrial development in Ireland and Scotland

Last year you responded favourably to the request of Mr Donal Murphy (IDA-Ireland), to participate in a multi-stage research project and facilitated interviews with several of your staff members

We are now starting the second phase of the research project Your participation at this stage would involve an interview during which you are invited to discuss a number of strategic issues at a corporate and subsidiary level Furthermore, as discussed last year, I would like to meet a number of your staff members for a second interview

I will contact you next week, to ascertain whether you are able to participate and, if so, to arrange a suitable date

Yours sincerely,

Drs Chris van Egeraat
Dublin City University Business School
Economics and Finance Group
Tel 01-8681729

APPENDIX B QUESTIONNAIRES

B 1 QUESTIONNAIRE FOR INTERVIEW 1

Time Based Competition and Spatial Configuration of Networks

DCU Business School (in co-operation Forfas and IDA Ireland)

Project co-ordinator Drs Chris van Egeraat (Tel 8681729 Fax 7045446)

Company name
Start of operations
Start of computer production
Number of employees

1 Please discuss governance structure of the company

2 Product lines/activities of this facility

3 Geographical market served by this facility

4 Please discuss location of manufacturing and logistics facilities

5 Please discuss the 'assembly chart' of the different product lines in relation to the inbound logistical arrangements

- Please discuss level of integration of incoming enclosures
- Who designs and who manufactures the motherboards?
- Are any of the systems manufactured by contract manufacturers?
- Are any of the systems manufactured on a full turnkey basis?
- Has this always been the case?
- Activities of other subcontractors?
- Please discuss organisation of inbound logistics
- Please discuss outbound logistical arrangements?

6 Please discuss <u>this subsidiary's</u> involvement in R&D and design

7 Please discuss <u>this subsidiary's</u> contact with suppliers regarding

- operational and logistics co-ordination
- technical/design partnership
- supplier development

8 Please discuss locational issues of suppliers (in relation to the entire company)

TIME BASED COMPETITION AND SPATIAL CONFIGURATION OF PRODUCTION NETWORKS

Dublin City University Business School (in co-operation with Forfas and IDA Ireland)
Project co-ordinator Drs Chris van Egeraat (Tel 8681729 Fax 7045446)

	Name of manufacturer	*Location of manufacturing*	*Logistics and organisational issues*
Complete systems (CEM)			
Housing / assembly			
Enclosures			
Bezel			
Other plastic parts			
Other metal parts			
Drive cages			
Screws and fasteners			
Racks			
Other			
Storage			
Hard disc drives			
Floppy disc drives			
Zip drives			
CD-ROM drives			
CD-RW drives			
DVD drives			
Tape drives			
Combo drives for portables			
Tape back-up/ autoloaders			
Other internal components			
Memory			
Microprocessors			
Motherboards			

Company name name interviewee date

	Name of manufacturer	Location of manufacturing	Logistics and organisational issues
Riser cards			
Network cards			
Modem cards			
Sound cards			
Video/graphics cards			
Power supplies			
Cooling fans			
Heat sinks			
Other			
Cables and Interconnect			
Power cable			
Drive interface cables			
Internal power cables			
AC adapter for portables			
Other cables			
Input Devices			
Key boards			
Mice			
Joysticks			
Microphones			
Digital Cameras			
Output Devices			
Printers			
Scanners			
Speakers			
Monitors/displays			
Other			
Country kits			
Media (CD-ROM/ Floppy disk)			

Company name name interviewee date

	Name of manufacturer	Location of manufacturing	Logistics and organisational issues
Printed media			
Mouse mats			
Batteries for portables			
Printed labels			
Laptop covers			
Docking stations			
Packaging			
Other			
Inputs for PCBA line			
Unpopulated boards			
Microprocessors			
Memory			
Other semiconductors			
Capacitors			
Resistors			
Surface-mount interconnect parts			
Jumpers and Switches			
Batteries			
Other			
Inbound Logistics partners			
Outbound Logistics partners			
Maintenance/service partner			
Out-plant labour services			

Company name name interviewee date

B 2 QUESTIONNAIRE FOR INTERVIEW 2

New High Volume Production and Spatial Configuration of Networks

DCU Business School (in co-operation Forfas and IDA Ireland)

Project co-ordinator Drs Chris van Egeraat (Tel 01-4542044, Fax 01-7045446, e-mail cvane@tinet ie)

GENERAL

1 Start of computer production
2 Total investments in fixed assets
3 Number of employees _____ Of which temporary labour ______%
4 Turnover m 1998
5 Number of units manufactured in 1998
6 Value of exports in 1998

ORGANISATION AND STRUCTURE

7 Please, briefly discuss the position of this plant within the organisational structure of European operations

8 Please, give location of the following activities in Europe

- European headquarters (or division offices)
- European R&D facilities/activities
- Headquarters European marketing
- Headquarters European sales
- European telesales centre
- European technical support centre
- Distribution centres in Europe
- Other facilities in the region

9 Your company has a number of similar assembly operations in each of the main markets of the world Please evaluate the role of the following factors for having an assembly operation in Europe

	Not important 1	2	3	4	5	6	Very important 7
Hold down the delivery time/distribution cycle time							
Hold down transport costs							
Overcome (potential) trade barriers							
Exchange rate issues							
'Being in touch' with the needs of the European market							
Other, please specify							

Name interviewee, name company, date

10 Please evaluate the importance of the following factors in locating/expanding your European assembly operation in Ireland or Scotland

	Not important 1	2	3	4	5	Very important 6	7
Labour costs relative to other European locations							
Managerial skills base							
R&D/technical skills base							
Availability of manual labour							
English speaking workforce							
Local industrial relations regime							
Flexible labour force							
Fiscal incentives							
Financial grants							
Local supplier network							
Local capability of logistics providers							
Institutional support system							
Land costs							
Local technology base (e g research institutes)							
Location of competitors (following comp)							
Other (please specify)							

11 Please mark local autonomy-levels in the areas listed below, and identify the location of decision-making

	No involvement 1	2	3	4	5	6	Full autonomy 7	Location of final decision
Product portfolio/ product strategy								
Production process/ manufacturing system								
Sales and marketing								
Product pricing								
Further investments								
Purchasing/ supplier selection								

CUSTOMER RELATIONS

12 Please discuss the way in which you have segmented your customers

13 Please discuss the present channel strategy *(discuss number of partners etc and level of integration)*

14 Please estimate the order lead time for the various segments

THE ASSEMBLY FACTORY

15 In relation to computer assembly, do you employ a cell or a line production? Or is it a mix?

16 Is there a difference in the batch size for the various product varieties/segments?

17 How important are the following strategies to this company in addressing the problem of fluctuating demands

	Not important 1	2	3	4	5	6	Very important 7
Numerical flexibility (overtime, part-time and temporary workers)							
Subcontracting (systems and/or components/processes)							
Changing production to a different product							
Multi-locational capacity management							
Adjust marketing (to smooth production)							
Manufacture to stock							
Other (please specify)							

18 In case you produce motherboards on site, is this activity part of a computer integrated manufacturing system, linking it to the system assembly plant?
Yes___ No___

Component sharing modularity is realised when the same component is used across multiple products Component swapping modularity is realised when different components are paired with the same basic product Finally, bus modularity is obtained when a standardised structure allows variation in the type number and location of modules that can plug into it

19 How many enclosure models do you use and to what extent are they standardised (allowing for component sharing modularity or component swapping modularity)

20 How many motherboard models do you use (before the integration of microprocessor and RAM) and to what extent are they standardised (different boards usable across multiple products)

21 Has your company worked towards other ways of component swapping/sharing modularity

____
Name interviewee, name company, date

THE SUPPLY CHAIN

22 *Discussion of the gaps in the information left after first interview and queries*

23 With respect to the systems build by your CEMs

a to what extent are these systems customised/standardised to individual customer requirements
b to what extent do these CEMs manufacture to order (or do they roll out an agreed number of units)

24 do the CEMs ship directly to the customer?

25 Do you employ subcontractors or contract labour on site?

26 How do you try to smooth production for the suppliers?

27 Please discuss the company's sourcing strategy (relevance of issues like reducing the number of suppliers per component and single/dual sourcing) What is the logic behind this strategy *(Probe the issues of stimulating partnership, decreasing complexity, stimulating competition for non-strategic parts, effect of supplier capacity, effect of supplier capacity or effect of required variety, etc*)

28 I have found that a number of parts/components are typically sourced from suppliers with a manufacturing presence in Ireland/Scotland/Wales/England In your opinion, what differentiates the products listed below (or their suppliers) from products that are sourced from other regions? *(Probe the issues of component characteristics (value, weight), level of customisation, customer power)*

- Enclosures
- PCBA
- CD-ROM pressing and printed matter
- Cables/interconnect
- Keyboard localisation
- Packaging
- Monitors

29 Which of the suppliers located in Ireland[/Scotland] also supply other assembly facilities of your company world-wide and which of the suppliers located in Ireland do not supply other assembly facilities of your company world-wide?

List local suppliers

30 Which of your suppliers located in Ireland[/Scotland] also use facilities in other regions to supply your company world-wide?

List local suppliers

31 Please discuss the contact that this facility (or regional product development group) has with its suppliers regarding product and process development and/or ongoing technical co-ordination (intensity and content of face-to-face contact moments)

32 Are suppliers' engineers resident at this subsidiary or does this subsidiary share personnel with the major suppliers for component/product development reasons? Please discuss

33 How important were considerations regarding product and process development and/or ongoing technical co-ordination, for your decision to choose a supplier with a 'local' manufacturing presence?

	These considerations played no role 1	2	3	4	5	6	These considerations played a very important role 7
Supplier a							
Supplier b							
Etc							

34 How important were logistical (*chain cycle time*) consideration for your decision to choose a supplier with a 'local' manufacturing presence?

	Choice for supplier with local manufacturing presence is not influenced by logistical considerations 1	2	3	4	5	6	Logistical considerations played a very important role 7
Supplier a							
Supplier b							
Etc							

35 In general, how important has government pressure/stimulation been for your decision to choose a 'local' supplier?

Played no role						very important role

36 If none of the suggested reasons (logistics, technical co-ordination, government stimulation) is relevant for your choice of a local supplier, what is the main reason for your decision to choose the particular local supplier?

37 Please discuss the organisation of supplier selection on a corporate level How is this subsidiary involved in supplier selection? Can you put forward suppliers? Examples?

38 Please discuss this subsidiary's involvement in supplier development (defined as policies, procedures and practices for assessing and improving supplier capability and performance in multiple areas such as quality, design support, and delivery) Which local suppliers did benefit?

39 Does this company discuss regionally strategic investments with its main suppliers? Please give examples

40 Does the organisation of logistics between this subsidiary and its local suppliers require regular face-to-face contact? Is this different for suppliers without a local manufacturing presence?

41 What is the logic behind the fact that some components are sourced local but are also sourced from other regions (e g enclosures and PCBAs)? *[Probe the relevance of the cost of the dies]*

LOCAL IMPACT

42 Please estimate the expenditure in the national economy (and percentage of total expenditure) in 1998 As regards parts and components, please only include those parts that are actually manufactured in the national economy

	Expenditure in local economy	*Percentage of total expenditure*
Parts/components		
Services		
Wages		

43 Please estimate the percentage of total parts/components actually manufactured in Ireland and Britain together in 1998

44 Has your company's, or other microcomputer companies', local demand for inputs encouraged
- a The establishment of subsidiaries of other MNEs in Ireland/[Scotland]?
- b The development of new suppliers in Ireland/[Scotland]?

If yes, please give examples

45 Did your local suppliers have to adapt in order to become approved suppliers?

	Expand capacity	Upgrade process technology (machinery)	Upgrade product technology/ expand product range	Upgrade organisational routines (Including JIT supply WCM TQM etc)
Supplier a				
Supplier b				
Etc				

46 What has been the improvement in and/or adaptations of the local infrastructure to meet your plant's needs?

47 Please discuss links (if any) with the local
- a Research institutes
- b Business Associations

INBOUND LOGISTICS

48 Please discuss your inbound logistics strategy *(discuss whether the company works towards a particular logistics organisational form – ownership of inventory, use of 3pls/ vendor hubs, required inventory levels)*

a In case of which parts/components do you take ownership of the inventories (in either on-site or off-site warehouses)?
b How many weeks inventory do you hold for these parts/components?
c How many weeks inventory do you require for vendor hubbed parts in 3pl?
d How many weeks inventory do you require for other vendor hubbed parts?
e Which components are manufactured in a near-JIT environment (virtually no buffers
f In relations to vendor hubbed inventories what is the level of inventory you are liable to take at some point *(e g 10 days liability would mean that, in case you want to kill the product off, you are liable to take the 10 days agreed inventory level in the hub)*
g Is this period different for customised - standardised parts?
h Where are the 3pl warehouses located?
i Are these 3pl warehouses company specific or can they consolidate inventories destined for different assemblers?
j In case you get material shipped from other continents (not hubbed), who owns the in-transit inventory?
k What are the service-time requirements to supply your plant and what does this mean geographically?

49 What (buffer) inventory do you require your suppliers in Ireland/UK (i e with regional manufacturing facility) to hold? What is the level of inventory you are liable to take?

	Number of days inventory	Liability
Regional enclosure suppliers		
Regional motherboard suppliers		
Etc		

OUTBOUND LOGISTICS

50 Please outline the organisation of outbound logistics in Europe *(including location of various centres)*

51 Which parts of the total order are not merged at this site *(prompt monitors, printers, country box etc)*?

52 Where does the merging of the total order take place?

PRODUCT AND PROCESS DEVELOPMENT

53 What does 'product development/design' mean for this company? *Prompt in particular the* <u>*R&D/ technical co-ordination issues*</u> *For example, if a system includes a new component or peripheral, what would be the development effort from your company's side? Other possible issues are innovative marketing, brand development, distribution and customer service*

54 In the 'home country' (U S), are production, marketing, and R&D activities in the same location? If not, what is the location of product development

55 Does the development team include marketing and production staff?

56 Please expand on the level of integration of the development systems of your company and your main suppliers

57 Mode (e g face-to-face), and intensity of communication between both development systems on product or process development issues

58 Does the company share personnel with the major supplier companies for component/product development reasons?

59 Discuss the extent to which the company differentiates its products for specific geographical markets *(e g specific products for North America, Europe and Asia, or global products)*

60 Does this require a 'product development team' in Europe?

61 Please discuss the R&D related departments in this facility

62 Please discuss the involvement of this subsidiary in product/process development (e g contact between local staff and corporate design facility)

63 Which of the following functions are carried out in this facility

System design	
Prototype production	
Evaluation of prototype	
Parts design	
Parts prototype production	
Evaluation of parts	
Technical support for procurement of parts for local production	
Process design	
Evaluation of corporate process design	

64 If regional marketing/ product development group is not located on site, please discuss the mode (e g face-to-face), intensity and content of communication between these groups and this production facility

HR AND TRAINING

65 Please estimate the number of employees in each of the following employment categories?

	Number of employees (FTE)
Managerial/supervisory and professional staff (including areas such as general, operations, purchasing, sales and logistics management)	
Research and Development	
Engineers (not R&D) (test, process, maintenance, facilities, etc)	
Technicians (typically having technical qualifications)	
Production operative – skilled	
Production operative – non-skilled	
Marketing/sales/customer service staff	
Call centre – sales	
Call centre – technical support	
Clerical/administrative	

66 Please estimate the percentage of the workforce that have
University degrees ___%
Technical College certificate/diplomas ___%

67 Please estimate the expenditure on wages in 1998 (or last fiscal year) £______

68 Please estimate the percentage of workers organised into teams? _____%

69 Does the company recognise trade unions?

70 How many former employees started their own company? _____
(Please give examples)

71 Which upper-level management positions are filled by non-nationals

72 What percentage of the middle and upper-level management positions is filled by non-British or non-Irish Nationals? ____%

73 Please name the three companies from which you experience strongest competition in recruiting
a Operations Managers
b Technical/Engineering staff
c General operative staff

74 Please estimate the percentage of operations/general management and technical/engineering staff that was previously employed by the sectors represented by the companies mentioned above _____%

75 Please discuss the career-path of the MD or Site Manager in this respect

76 Please estimate the training budget / resources spent on training in 1998 (including labour costs for people while on courses, cost of internal trainers, fees paid to external trainers, travel, equipment and subsistence) £______ and as a percentage of total labour cost ____%

Name interviewee, name company, date

77 Please, briefly outline your internally and externally managed training activities

- Organisation of training
- Please estimate the percentage of training hours that is internally managed
- Please estimate the percentage of training hours of internally managed training which takes place 'on the job' ____%

78 Please discuss links (if any) with the local
- Universities/colleges
- Training institutes

Prompt internship, provision of on-site and on-site training/education, discussion of colloquium at local colleges, participation of colloquium, etc

79 Have any training programmes or other schemes been introduced to address your (or your sector's) skill needs/labour shortage problems? (e g government training agency, or extra university places)

80 In what way, if any, has the company contributed to these schemes?

81 Please estimate the number of training days in 1998 received by the following employment categories (aggregate for the groups) And, please evaluate (on a scale from 1 to 7) your company's contribution to the skill levels in the local (Irish/Scottish) labour market?

	No of training days
Managerial/supervisory and professional	
R&D staff	
Engineers	
Technicians	
Production operative – skilled	
Production operative – non-skilled	
Technical support call centre	
Marketing/sales call centre	

82 Please estimate the (aggregate) number of training days (1988) aimed at the following skills

	Number of days
Induction (health and safety etc)	
Hardware (machinery, materials and technology)	
Software skills (packages and program languages in support of technicians and manufacturing (e g test applications, visual basic, visual C ++, Unix etc)	
Management training (managing people, understanding culture, goal setting)	
Softer skills (team leading, project management, attendance, productivity,}	
Other Software skills (company system, database packages, word processing etc)	
Marketing /sales / Languages	
Other	

83 Please estimate average hours of training received in 1998 by a new production worker (induction) _____ hours

84 Please estimate the average duration (gross) of off-the job <u>production related</u> training courses (please ✓ as appropriate)

<1 day	
1 day - 1 week	
1-4 weeks	
4-8 weeks	
> week	

85 Please estimate the share of the total training days that leads to an externally recognised certificate/diploma/degree etc ___%

86 To what extent does training or experience lead to mobility between grades? (please tick on a scale from 1 to 7)

to no extent 1	2	3	4	5	6	to a great extent 7

Name interviewee, name company, date

B 3 Postal Questionnaire

New Production Concepts and Spatial Configuration of Networks

DCU Business School (in co-operation with Scottish Enterprise)

Project co-ordinator: Drs. Chris van Egeraat. (Tel. 00-353-1-4542044 Fax. 7045446, e-mail cvane@tinet ie)

Dear Sir or Madam, with this questionnaire we aim to establish the relevance of a number of new high volume production concepts to the computer hardware industry

- Some of the questions pertain to the corporation as a whole, while others pertain to the situation at this subsidiary
- Most questions ask you to score ***on a continuum*** running from 1 to 7 You are requested to ***tick (✓) a box for items in each question as appropriate***
- If you have the feeling that a question is not relevant, please leave this question blank

Customer relations

1 Does the company offer a small or a wide variety of computer systems?

a very limited variety						an extensive variety
1	2	3	4	5	6	7

2 To what extent are the products customised to individual customers?

not at all						100%

3 How important is it to respond quickly to customer demand for changes with new or modified products?

not at all important						absolutely essential

4 What, approximately, is the median age of product offering in the European market? ____ month

- How prominent are the following goals in your distribution strategy?

	Receives no particular attention 1	2	3	4	5	Very important part of our strategy 6	7
5 Minimise the order to delivery cycle time							
6 Minimise the distribution cycle time (throughout the channel)							
7 Maximise delivery reliability/consistency							

8 How would you describe the level of integration between assembler and the distribution channel? Arm's length relationship, strongly integrated, or somewhere in between?

arm's length relationship						strongly integrated value chain

- How intensive does this company share the following *information* with the downstream channel partners (distributors, retailers, value added resellers, etc)? (if not relevant tick here __)

	No info Sharing 1	2	3	4	5	6	Intensive info sharing 7
9 Current demand for end-products							
10 Demand forecasts							
11 Future product development projects							

12 How intensive are your efforts to build a long-term relationship with your customers?

no efforts						central to our strategy

13 What percentage of output of this subsidiary (units) is built/assembled to order? Approx ___ %

14 What percentage of output (units) is actual end-customer ordered (assembly of individual orders that are specified by the customer at the end of the chain?) Approx ___ %

15 Do you have agreements with customers / channel partners, stipulating the procurement of a number of standardised systems per unit of time?
Yes ___
No ___
If yes, roughly what percentage of output (units) does this represent? Approx ___ %

16 Are the sales people (at the end of the chain) tied directly to the factory scheduling function?
Yes ___
No ___

17 How would you describe the negotiations with the distribution channel? Cut throat, strong partnership, or somewhere in between?
(if not relevant tick here ___)

cut throat						strong partnership

Research and development

18 How important are product innovations (e g new features, new technologies, new products) to the success of your business

not at all important						crucial

19 How important is it to respond quickly to customer demand for changes with new or modified products?

not important for the success of our business						crucial for success of our business

- How important are the following goals in the company's R&D strategy?

	1 Receives no particular attention	2	3	4	5	6	7 Very important part of our strategy
20 Minimise new product development / introduction time							
21 Maximise rate new product introduction							

22 How important are incremental innovations (e g new features, modified products) versus breakthrough innovations (e g new products, new technologies) to the success of your company?

incremental						breakthrough

23 In the product design process, what attention is paid to the manufacturability of design

limited attention						central to design process

24 In your company, to what extent are product and process development activities integrated? Is it carried out sequentially and in separate teams, simultaneously in one team, or is it somewhere in between

sequentially and in separate teams						simultaneous and in one team

25 To what extent does the company use flexible technologies (e g CAD) in the development process?

not used						used to a great extent

The assembly factory

26 Where does your assembly process lie on a scale between fully standardised mass production and one-of-a kind production (where each final product is different from the next)?

fully standardised mass production						one-of-a kind production

27 With respect to system assembly, please estimate the average batch size?________ units

- How prominent are the following goals in your production strategy?

	1 Receives no particular attention	2	3	4	5	6	7 Very important part of our strategy
28 No or small buffer inventories							
29 Increase inventory turnover							
30 Minimise the lot size							
31 Minimise set-up times							
32 Bring down production cycle time (per major phase of main sequence)							
33 Maximise value added as percentage of total elapsed time							

- To what extent are the following management philosophies adopted in your production strategy?

	To no extent						To a great extent
34 Total process efficiency							
35 Elimination of waste							
36 TQM							
37 Continuous process improvement							
38 Flexible production (*the ability to change quickly between products*)							
39 Integration of thinking and doing (*worker involvement in defining and improving the process*)							

40 To what extent is flexible machinery used in the assembly process?

not used						used to a great extent

41 To what extent do you employ computer-aided production management techniques in system assembly?

not at all						used to a great extent

The supplier relations

42 How would you describe the level of integration of the company with its suppliers? Arm's length, strongly integrated or somewhere in between?

arm s length relationship						strongly integrated

43 In those cases where the company integrates suppliers' new component technology to what extent are the development systems of both companies integrated?

not at all						strongly integrated systems (e g cross-organisational teams)

- How prominent are the following goals in your sourcing strategy?

	Receives no particular attention 1	2	3	4	5	6	Very important part of our strategy 7
44 Minimise inventories of parts / Increase frequency of deliveries							
45 Reduce inventories at suppliers							
46 Minimise chain cycle time							
47 Continuos improvement of supplier performance (quality, cost and service)							

48 With respect to your supplier relations, what is the relevance of the following statement "There is a joint approach to total quality" (e g interaction and mutual agreements on quality targets)

of no relevance — very relevant

49 With respect to your supplier relations, what is the relevance of the following statement "There is transparency and open discussion of costs and a rational framework for determining costs, price and profits" (versus tendering)?

of no relevance — very relevant

- How intensive does the company share the following information with its main suppliers?

	No info Sharing 1	2	3	4	5	6	Intensive info sharing 7
50 Inventory data							
51 Current demand for end-products							
52 Demand forecasts							
53 Future product development projects							

54 To what extent does your company make efforts to smooth production for its suppliers (limit the percentage change in the size of successive orders)?

no effort — intensive effort

55 What is the company's policy with respect to supplier development/assistance Do you have a structural programme for assisting your suppliers or do you provide no assistance at all? Or is it somewhere in between (supplier development is defined as policies, procedures and practices for assessing and improving supplier capability and performance in multiple areas such as quality, design support, and delivery)

no assistance — structural assistance programme

56 To what extent do you consider yourself the organiser of a production chain? To no extent, to some extent (only involving a number of products) or to great extent?

to no extent — to a great extent

57 To what extent does the company differentiate its products for specific geographical markets (e g North America - Europe - Asia)?

to no extent (global products) — to a great extent

58 If products are (geographical) market specific, to what extent is this facility involved in the development of these market specific products?

no involvement — systems sold by this subsidiary are developed locally

59 Would you consider the organisational structure of your company strongly hierarchical, strongly networked (flat organisational structure) or somewhere in between?

strongly hierarchical						strongly networked (flat)

- How prominent are the following goals in your overall business strategy?

	Not important						Central to our strategy
60 Removing time throughout the value chain							
61 Reduce decision making time							

The nature of competition

62 Is competition in your industry based totally on product differentiation, totally on price competition, or is it somewhere in between?

price competition			both			product differentiation

63 Are product life cycles of products in your business unit's industry very long and predictable, very short and unpredictable, or somewhere in between?

long and predictable						short and unpredictable

B 4 Questionnaire for Telephone Interview

New High Volume Production and Spatial Configuration of Networks

DCU Business School (in co-operation Forfas and IDA Ireland)

Project co-ordinator: Drs. Chris van Egeraat. (Tel: 01-4542044, Fax: 01-7045446, e-mail cvane@tinet.ie)

Company Name

Component	*Name and location supplier*	*Logistical arrangement (hubbed or your own inventories)*	*Typical mode of transport (from location of manuf. to hub or your own facilities) (ship or plane)*	*Target number of shipments per month (into hub or your facilities)*	*Target inventory levels (in hub/ your w'house or suppliers local man. plant) (days)*
Material input A	Supplier A				
	Supplier B				
	Etc				
Material input B	Supplier A				
	Supplier B				
	Etc				
Etc	Supplier A				
	Supplier B				
	Etc				

Company name name interviewee date

APPENDIX C EXAMPLE OF TABLE WITH SUPPLY CHAIN DATA USED IN ANALYSIS (EXAMPLE GATEWAY)

Gateway	*Name and nationality of supplier*	*Location of manufacturing*	*Logistical arrangement*	*Typical mode of transport (from location of manuf)*	Target number of shipments per month	Target inventory levels (days)
Enclosures	Axion (Far East)	Taiwan/Mexico	3pl hub	Ship	4	10
	Likon (Far East	Malaysia	3pl hub	Ship	4	10
Server enclosures	No data (USA) (low volume)	USA	3pl hub	Plane	1	10
Partly integrated portables	Quanta (Taiwan)	Taiwan	Not hubbed, supplied direct to Gateway w'house	Plane	4	10
	Sanyo (Japan)	Japan	Not hubbed, supplied direct to Gateway w'house	Plane	4	10
Docking stations for portables	Supplied by the suppliers of partly integrated portables	Taiwan and Japan	Not hubbed, supplied direct to Gateway w'house	Plane	4	10
Server racks	No data (USA)	USA	3pl hub	Ship	4	10
Motherboards	Intel (USA)	Malaysia	Not hubbed, supplied direct to Gateway w'house	Plane	4	10
	Elite (Hong Kong)	Mexico	Not hubbed, supplied direct to Gateway w'house	Plane	4	10
	Jabil (USA)	Mexico	3pl hub	Plane	4	10
Microprocessors	Intel (USA)	Penang etc	Not hubbed, supplied direct to Gateway w'house	Plane	4	5
Memory	Micron (USA) Samsung (Korea) Hyundai (Korea) LG (Korea) Toshiba (Japan) Siemens (Germany)	Korea Japan Korea Korea Japan Germany	3pl hub	Siemens truck Others plane	4	10
Power supplies	Powertech (Taiwan)	Malaysia/China	3pl hub	Ship	4	10
	Astec (USA)	China/Mexico	3pl hub	Ship	4	10
AC adapters for portable	Delta (USA) and Newton (USA), but comes integrated with portable	Far East	Comes with portable			
Batteries for portable	Sanyo (Japan), but comes integrated with portable	Japan	Comes with portable			
Cooling fans	No data	Far East	3pl	Ship	2	10
	Some come with power supply	Far East	Comes with power supply			

Gateway	Name and nationality of supplier	Location of manufacturing	Logistical arrangement	Typical mode of transport (from location of manuf.)	Target number of shipments per month	Target inventory levels (days)
Heat sinks	Redpoint Thermalloy (UK) (some come with the processor)	Far East	Not hubbed, supplied direct to Gateway w'house, 3pl in 2001	Ship	2	10
Hard disc drives	Quantum (USA) configured drives from MKIR (Japan)	Quantum Dundalk MKIR Dundalk and Far East	Hubbed at Quantum	Far East plane Ireland truck	4 from Far East, 20 from Ireland	5 at finished level and 5 at generic level
	IBM (USA)	Hungary	3pl hub	Truck	4	10
	Western Digital (USA)	Far East	3pl hub	Plane	4	10
	Toshiba (Japan)	Japan	3pl hub	Plane	4	10
Hard disc drives for portable	IBM (USA)	Hungary and Russia	3pl hub	Truck	4	10
Floppy disc drives	Panasonic (Japan)	China	3pl hub	Plane	4	10
CD-ROM drives	Mitsumi (Japan) and Toshiba (Japan)	Japan	3pl hub	Plane	4	10
	Plextor (small amounts)	Taiwan	Plextor hub in The Netherlands	Plane	4	10
LS-120 drives	Mitsubishi (Japan)	Japan	3pl hub	Plane	4	10
TR5 Tape units	Seagate (USA)	Far East	3pl hub	Plane	4	10
Zip drives	Iomega (USA)	Far East	Not hubbed, supplied from w'house in the Netherlands	Plane	4	10
CD RW drives	Philips (The Netherlands)	Far east	Philips hub in The Netherlands	Plane	4	10
DVD drives	Toshiba (Japan)	Japan	3pl hub	Plane	4	10
Combo drives	Toshiba (Japan) (comes integrated with portable)	Far east	Comes with portable			
Network cards	3-com (USA)	Dublin (majority) and overseas (minority)	Vendor hubbed at Walsh Western	Plane if from overseas	Overseas 2	10
	Olicom (Scandinavia)	Far East	3pl hub	Plane	2	10
Network PC cards for portable	Xircom (USA)	Belgium	3pl hub	Plane	2	
	TDK (Japan)	Japan	Not hubbed, TDK w'house UK	Plane	2	10
	3-com (USA)	Dublin and USA	Hub at Walsh Western	Plane	2	10

Gateway	Name and nationality of supplier	Location of manufacturing	Logistical arrangement	Typical mode of transport (from location of manuf.)	Target number of shipments per month	Target inventory levels (days)
Sound/ video/ graphics cards	ATI (Canada) (Graphics) STB (USA) (Graphics) Creative Labs (Singapore) (Sound)	Malaysia/Indonesia Mexico Singapore	Hubbed	Flown	4	10
Display Monitors	LG (Korea)	Wales	3pl hub	Truck	20	10
	Mitsubishi (Japan)	Japan	3pl hub	Ship	4	10
	Hitachi (Japan) (high-end, low volume)	Japan	3pl hub	Ship	4	10
	Sony (Japan) (high end, low volume Stopped in '99)	Wales	3pl hub	Ship	4	10
Display for portable	Toshiba (Japan) Mitsubishi (Japan) ADI (Taiwan) LG (Korea) (come all integr with portable)	Japan Japan Taiwan Korea	Come integrated with portable			
Screws and fastenings etc	No data	No data	Stocked by turnkey supply-chain- manager QEF Cork	No data	20 from QEF to Gateway plant	1 day on-site but large stocks at QEF
Country kits	On-site (Modus Media from 2001)					
CD-ROMs	Modus Media (USA) for wrapping and distribution and limited CD-R manufacturing Actual CD-ROM sourced from others, incl Sonopress Dublin	Shrink wrapping in Kildare CD manufacturing e g in Dublin	Modus functions as turnkey supply-chain-manager and stocks CD-ROMs	Truck	20 from Modus to Gateway plant	15 days (wrapped)
	Thompson Litho (USA)	Scotland	Thompson hub Dublin	Truck	No data	No data
	Dureco (France)	France	No data	Truck	No data	No data
	Microsoft software from Zomax (USA)	Dublin	Hubbed at Zomax	Truck	20 from Zomax to Gateway plant	No data
Printed media	Modus Media (USA)	Printed in Kildare and wrapped with CD-ROM	Hubbed at Modus	Truck	20 from Modus to Gateway plant	15 days (wrapped)

Gateway	Name and nationality of supplier	Location of manufacturing	Logistical arrangement	Typical mode of transport (from location of manuf)	Target number of shipments per month	Target inventory levels (days)
High volume keyboard models	Lite-on (Taiwan)	Far East	Hubbed at Lite-on/ Maxi Switch Limerick	Ship	6 into Maxi Switch	10
Low volume keyboard models	Lite-on/ Maxi Switch (Taiwan)	Printing in Limerick	Almost true JIT	Truck	20	8 at generic level and 2 at finished level
	Small amounts from Microsoft (USA)	Printing in The Netherlands	Almost true JIT	Truck	No data	No data
Mice	Microsoft (USA)	Far East	Via turnkey supply-chain-manager BG Turnkey in The Netherlands	Truck	6 from BG Turnkey to Gateway	No data
Mouse mats	Techmatic (Ireland)	Drogheda	Via turnkey supply chain manager Modus Media in Kildare	Truck	4	No data
Joy sticks	Arcadia (no data) Logitech (Switzerland)	Far East Far East	3pl hub	Ship	4	10
Speakers	Altec Lansing (USA) Boston Acoustics (USA)	Hong Kong China	3pl hub	Ship	4	No data
Printers (little)	Epson (Japan)	Majority Malaysia, some Telford, England	3pl hub	Ship (Malaysia) Truck (Telford)	4 from Malaysia	10
Scanners (little)	HP (USA)	No data	3pl hub	No data	4	10
Digital Cameras (little)	Sony (Japan)	Far East	3pl hub	No data	No data	No data
Power cords	LD Intercon (Germany)	Ireland	Hubbed at LD Later kitted by Modus Media	Truck	8	10
Internal current and signal cables	Keytech (Ireland)	Limerick	3pl hub	Truck	8	10 was requirement but they probably held more
Packaging	Smurfit (Ireland ILP (Ireland)	Dublin/Belfast Dublin	Almost true JIT, direct to Gateway plant	Truck	20	1 day on-site at Gateway, small at suppliers
Printed labels	Cuspal (Ireland)	Ireland	Hubbed at Cuspal	Truck	No data	No data

APPENDIX D DETAIL OF FOCAL COMPANIES' REGIONAL SUPPLIERS

Table D 1 Products supplied by focal companies' suppliers in Ireland, Scotland, England and Wales

	Dell	*Gateway*	*IBM*	*AST*	*Apricot*	*Digital*	*Sun*	*Compaq*	*Apple*	*Intel*	*Packard Bell*
Supplier plants in Ireland											
3-Com-US Robotics, Ireland	modem PC cards and LAN adapters (small bits)	network cards			network cards						
Alps Electric, Millstreet Ireland			keyboard localisation						keyboard localisation	keyboard localisation	
APW (C-Fab) Dublin, Ireland						enclosures sent to CTS for sub-assembly	chassis for mass storage works (small amounts)				
APW (Horman Electronics) Cork Ireland									assembly and test of complete systems		
AVX Coleraine Northern Ireland						capacitors and resistors					
Ballymount (Trend) Lucan Ireland	metal for enclosures							sheetmetal brackets	metal enclosures and sub assemmbly of speakers		
BG Turnkey services Cork Ireland	TSCM and wrapping of media								keyboard local (NMB) TSCM for media country kits		
BG Turnkey services, Dublin Ireland		TSCM for mice (small)								TSCM and kitter of accessory kit	
BG Turnkey services, Limerick Ireland	TSCM and wrapping of media			TSCM and kitter of accessory kit							
Burex Dundalk, Ireland	printed mousemat										
Cabletron Limerick Ireland						network cards and hardware					

	Dell	*Gateway*	*IBM*	*AST*	*Apricot*	*Digital*	*Sun*	*Compaq*	*Apple*	*Intel*	*Packard Bell*
Chip, Hollyhill, Ireland									rework		
Colorman Dublin Ireland									printing sent to BG Turnkey		
CTM Southborough Kells, Ireland	metal enclosures			metal enclosures		encl s for some servers and storage				metal parts for sub-assembly	
Cuspal, Dublin Ireland		labels									
Datapackaging (Trend), Mullingar Ireland	plastic for enclosures								enclosures		
Digital, Galway Ireland						media					
EPC Dingle Ireland									cables		
Fitzpack Limerick Ireland	packaging			packaging							
Fullarton Limerick Ireland			enclosures (for a short period in 1999)								
Hiterm, Cork, Ireland									foam		
Intel Kildare Ireland	some of the processors	some of the processors	some of the processors	some of the processors (and m boards early 1998)	some of the processors			some of the processors and network cards		some of the processors and network cards	some of the processors
Ire-tex Group (ILP), Leixlip Ireland	boxes	boxes								boxes	
Ire tex, Limerick Ireland	boxes										
Irish Moulded Products Macroom, Ireland									srews etc		
Keytech, Limerick Ireland	cables	cables		power cables sent to BG Turnkey						power cables sent to BG Turnkey	
Keytronics Dundalk Ireland				keyboard localisation							
LD Intercon Offaly Ireland		cables									

	Dell	Gateway	IBM	AST	Apricot	Digital	Sun	Compaq	Apple	Intel	Packard Bell
Lite-on (Maxi Switch) Raheen Limerick	keyboard localisation	keyboard localisation									
LMS-Beach (since 2000 Flextronics Enclosures) Tullamore Ireland	enclosures							server enclosures and sub-assembly			
MacB Cork Ireland									TSCM for screws etc	TSCM for screws etc	
Madge Networks (later Celestica), Dublin, Ireland							network cards (small quantities)				
McDonald Printing, Ireland				Printing sent to BG Turnkey							
Methode Limerick Ireland						cable assemblies and terminators	cables sent to BG Turnkey				
Modus Media Dublin Ireland (printing facility)	printed media sent to Modus Limerick	printed media sent to Modus Kildare	printed media sent to Modus Scotland				printed media sent to Modus Scotland				
Modus Media Kildare, Ireland		TSCM for media printing in Dublin, country kits		TSCM for CD ROMs sent to BG Turnkey							
Modus Media Limerick, Ireland	TSCM for media printing in Dublin country kits										
Molex Shannon and Millstreet Ireland			connectors	internal cables		surface mount interconnect material	cables			surface mount interconnect and cables	
MSL Athlone, Ireland				motherboards	board assembly for Apricot OEM bussiness						

	Dell	*Gateway*	*IBM*	*AST*	*Apricot*	*Digital*	*Sun*	*Compaq*	*Apple*	*Intel*	*Packard Bell*
Munekata Dublin	plastic for enclosures								plastic for enclosures		
Printech Clondalkin Ireland			high volume printed matter sent to Modus Media						printing sent to TSCMs	printed matter sent to BG Turnkey	
QEF Cork, Ireland	TSCM for screws etc	TSCM for screws etc		TSCM for screws etc					TSCM for screws etc		
Quantum Dundalk, Ireland	hard disk drive configuration	hard disk drive configuration	hard disk drive configuration and assembly of casing	hard disk drive configuration	hard disk drive configuration	pre-assembly of hard disk drives and tapes	hard disk drive configuration	hard disk drive configuration	hard disk drive configuration	hard disk drive configuration	hard disk drive configuration
Rennicks, Dublin, Ireland									small amount of plastic parts		
SCI Fermoy, Ireland	motherboards										
Smurfit (Connaucht Packaging Galway Ireland	boxes										
Smurfit Cork, Ireland									boxes		
Smurfit, Dublin Ireland		boxes									
Sonopress, Dublin Ireland		CD-ROM pressing, sent to Modus Media							CD-ROM pressing, sent to TSCMs		
Techmatic Drogheda Ireland		mouse mat sent to Modus Media									
Tech-source Cork Ireland									minor sub-assembly service to imported enclosures		
Top Tech Dublin Ireland				enclosures and metal parts							
Volex, Castlebar Ireland						signal cables and terminators	cables sent to BG Turnkey				

	Dell	*Gateway*	*IBM*	*AST*	*Apricot*	*Digital*	*Sun*	*Compaq*	*Apple*	*Intel*	*Packard Bell*
Walsh Western Cork, Ireland									kitting of country kits		
Worldmark Group (Industrial Print), Bray Ireland	metal labels and badges								printed labels for back of system		
Zomax, Dublin Ireland		CD-ROM replication, sent to Modus Media									
Supplier plants in Scotland											
AMP, Port Glasgow Scotland			connectors		connectors						
Amphenol Port Glasgow Scotland			cables			large part of cabels and some connectors					
APW (High Speed Production) Beith, Scotland			metal enclosures and sub-assembly service			metal cabinets sent to CTS for sub-assembly					
Arkol, Glasgow Scotland					foam			foam			
AVEX, East Kilbride Scotland							boards for low-end products				
Bermo Glenrothes Scotland							enclosures and subassembly				
BG Turnkey services Livingston, Scotland							TSCM for screws, etc kitting of ship kits	rework (small amounts)			

	Dell	Gateway	IBM	AST	Apricot	Digital	Sun	Compaq	Apple	Intel	Packard Bell
Birkbys, Glenrothes, Scotland						plastic sent to Quantum and Seagate for sub assembly	enclosures and subassembly	plastic components for drivebays			
Brands Electronics Greenock Scotland						hard disk drive subassembly		country kits enclosure and rack pre-assembly, pre-assembly of h d drives			
Chicony, Greenock, Scotland			keyboard localisation								
Clairemont Electronics, Greenock Scotland			contract labour services and cables suppy					subassembly service and cables			
CTS Corporation Glasgow, Scotland						backpanel manufacturing and sub-ass of storage units					
Dewar Brothers, Linlithgow, Scotland							boxes sent to BG Turnkey				
Elcomatic, Linwood, Scotland			contract labour services								
Fife Fabrications, Glenrothes Scotland						metal parts enclosures					
Foamplus, Linwood Scotland			packaging								management of packaging from Smurfit
Foxteq (Hon Hai) Rentrew Scotland								enclosures and sub-assembly			

	Dell	Gateway	IBM	AST	Apricot	Digital	Sun	Compaq	Apple	Intel	Packard Bell
Fullarton Computer Industries Kilwinning Gourouck Prestwick			complete systems enclosures and sub-assembly cables			enclosures for servers and storage works and sub-assembly		high volume encosures and sub-assemmbly, cables		enclosure and sub-assembly	all volume enclosures (from 1999)
Gardener Gibson Scotland								TSCM and wrapping of media			
Geltron Irvine, Scotland						TSCM for screws and fasteners					
Hamilton Packaging Clydebank, Scotland								plastic bags			
Inventech Renfreshire Scotland								complete low-end systems			
Jabil Circuit Livingston Scotland	notebook boards from 1999	server boards from 1999									
KWR Glasgow Scotland			packaging								
Livingston Precision, Livingston Scotland					enclosures (in the past)		enclosures and sub-assembly assmebly of imported racks				
MacFarlane (A&W Fullarton) Govan, Glasgow					boxes (some final assembly in glenrothes)	boxes		boxes			
MacFarlene Kilmarnock Scotland								packaging			
McKechnie, Beith Scotland			plastic bezels sent to enclosure manufacturer					plastic components for drivebay etc			

	Dell	*Gateway*	*IBM*	*AST*	*Apricot*	*Digital*	*Sun*	*Compaq*	*Apple*	*Intel*	*Packard Bell*
Modus Media Cumbernauld Scotland			TSCM for media low-volume printing, country kits				TSCM for media low-volume printing country kits				
Motorola Glasgow, Scotland			semi conductors			memory					
NABS, Greenock, Scotland			TSCM for screws etc								
NEC											memory
NMB Inchinnan Scotland			keyboard localisation		keyboard localisation	keyboard localisation		keyboard localisation			keyboard localisation
Phoenix Cables Irvine Scotland			cables			small amount of cables					
Printech East Kilbride Scotland (printing in Ireland)			low volume printed matter sent to Modus Media								
Rexem Corrugated (John Horn) Glasgow Scotland								boxes and some specialised printed matter			
SCA Edinburgh, Scotland			packaging								
Scotfoam Glasgow Scotland			packaging								
Seagate, Scotland						pre-assembly of plastic components to hard disk drives					
Simclar Dunfirmline, Scotland						flexible cirquit (from 1999 sub-assmebly of high-end servers)					cables (from 1999)
Smurfit Corrugated UK Tamockside and Irvine Scotland			boxes					boxes			boxes sent to Foamplus

	Dell	*Gateway*	*IBM*	*AST*	*Apricot*	*Digital*	*Sun*	*Compaq*	*Apple*	*Intel*	*Packard Bell*
Solectron Dunfermline Scotland	server boards						desktops and server boards pre-assembly of storage units	some of the motherboards (but most from Romania)			
Sonnel, Hillington, Glasgow Scotland								rework of memory chips			
Sykes Scotland (SDL International), Galashiels, Scotland					TSCM for CD-ROMs, printed media						
Techdyne Scotland Ltd Livingston, Scotland								very small amount of signal cables			
Thompson Litho East Kilbride Scotland		TSCM for CD-ROMs printed matter			TSCM for CD-ROMs printed media			TSCM for CD-ROMs, printed matter (part sent to Brands)			TSCM for CD ROMs printed matter
TR Fastenings East Kilbride Scotland								TSCM for screws ect			
Turnkey, Clydebank Scotland			sub-assembly services								
US Print Livingston Scotland							wrapping of media printing sent to BG Turnkey				
Volex Cumbernauld Scotland			cables			signal cables and terminators					
Worldmark Group (Donprint), East Kilbride, Scotland								labels			
Supplier plants in England and Wales											
Aavid High Wycombe England			heat sinks		heat sinks						

	Dell	Gateway	IBM	AST	Apricot	Digital	Sun	Compaq	Apple	Intel	Packard Bell
Celestica Manchester and Kitsgrove England	motherboards		motherboards				compl system assmebly server boards assembly of microproc module				
Epson Telford, England		final assembly of some printers									
Hewlett Packard Bristol England							tapes				
Hossiden Besson England							microphones sent to BG Turnkey				
LG Electronics, Newport, Wales		monitors									
Mclean Midwest (APW), Manchester, England						cooling fans sent to CTS					
Mitac Telford England							complete low-end systems				
Nimbus Cwmbran Wales		CD-ROM replication sent to Modus Media									
PSION Connect Milton Keynes England	modem for portable										
Redpoint Thermalloy Swindon England			heatsinks		heatsinks						
Retal, Porsmouth England	server racks							server racks			
Samsung Wynyard Billingham England			monitors					monitors			
Sony, Penwed (Bridgend) Wales		high end low volume monitors	monitors					monitors		monitors	
Tatung Telford England					monitors			monitors			

	Dell	*Gateway*	*IBM*	*AST*	*Apricot*	*Digital*	*Sun*	*Compaq*	*Apple*	*Intel*	*Packard Bell*
Unipower Lancing Sussex England						power supplies (small)					
Viasystems, Sunderland England					etched boards for PCBA line						
Volex Leigh England					power cords	power cords		power cords			

APPENDIX E INBOUND PIPELINE STRATEGIES AND STRUCTURES OF INDIVIDUAL FOCAL COMPANIES

This Appendix describes the specific pipeline strategies and structures of the individual focal companies At the time the first interviews were conducted, most focal companies had just changed their strategies and were in the middle of restructuring their inbound pipelines leading to a rather chaotic structure However, later rounds of interviews, carried out in the second half of 1999 and the first quarter of 2001 provided an opportunity to follow the restructuring process The data below pertain to the situation at the time of the first round of interviews – between end 1998 end start 1999 – unless different periods are specifically indicated

Dell

Dell's inbound logistics strategy was "to continuously reduce the dependency on the [Dell] warehouse" by requesting local suppliers to supply direct on a very frequent basis and making non-local suppliers hub, wherever it made sense (Interview O'Donnell, Dell, 1999) For Dell, 'local' meant in very close proximity Thus, Dell advertised very short supply-lead times "To sustain the direct model all suppliers must be within an hour of the plant" (Moran, 1998) "Our model is that our suppliers have to be within 20 to 30 minutes from the production lines " (*The Sunday Business Post*, 7/2/99) In practice, Dell was slightly more flexible and some enclosure suppliers, located at approximately two hours' drive from Dell, supplied direct as well[1]

At the time the first interviews were conducted, in November 1998, most of Dell's material inputs were either manufactured locally, hubbed locally, or supplied by local turnkey supply-chain-managers, such as QEF (for hardware), Keytech (for cables and interconnect), BG Turnkey and Modus Media (both for media)[2] Even the local manufacturers were requested to hold specified minimum levels of finished goods at their own premises The only items manufactured or printed on a nearly true JIT basis were low-volume keyboard models and most of the packaging material

Most material was hubbed Even the enclosures manufactured in Tullamore and the motherboards manufactured in Scotland and England were hubbed locally The only

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[1] LMS-Beach in Tullamore, at two hours' drive from Dell, hubbed finished enclosures near Dell in Limerick – initially at their second facility in Annercotty and from 1999, after the closure of the Annercotty facility, at the 3pl hub However, the main reason for not supplying direct lay in a lack of warehouse space at the Tullamore plant, rather than in a specific Dell requirement Having said that, at least until the opening of the new Dell EMF3 facility (see below), Dell preferred to have a certain amount of inventories hubbed nearby, even when production took place at only 2 hours' drive from Dell (Interview Roche, LMS-Beach, April 2001)

[2] Although some of these companies manufactured part of the supplies in-house, they also acted as turnkey supply-chain-managers, buying and storing components from various vendors For Dell, the local facilities of the two media suppliers were merely shrink-wrapping CD-ROMs and documentation Dell kitted its own country boxes

imported items that were not hubbed, were some motherboard and network card models (the ones supplied by Intel), microprocessors (Intel), some of the server enclosures, server racks, integrated notebook bases, and Zip drives[3] At the time of the second interview, in 1999, server racks and server enclosures were hubbed as well Furthermore, by this time Dell had started to assemble notebooks from scratch – hubbing the required components and phasing-out the direct supply of integrated notebook bases The reason for not hubbing Zip drives had to do with the fact that it involved a non-established supplier (Iomega)

In November 1998, there was a clear strategy to consolidate the hubbed inventories "We try to consolidate as much as possible in our two main hubs" (Interview Walsh, Dell, November 1998) These two main hubs were IEC and Walsh Western in Limerick Given the size and volumes involved, Dell deliberately chose not to concentrate all material at one single 3pl provider and dual-sourced the service The only companies supplying from other hubs were Lite-on (high-volume keyboard models, i e English language boards), Logitech (mice) and LMS-Beach The latter two hubs were remnants of earlier supply chain structures and proved short-lived [4]

Nearly all hubs and supply-chain-managers were located in very close proximity to Dell's main European Manufacturing Facility 1 (EMF1) Thus, Lite-on, LMS-Beach, BG Turnkey, Modus Media and Keytech, were all located on the same industrial estate The 3pl hubs were located in close proximity as well (see Figure 5 3), although both 3pl providers operated additional hubs in various European locations for 'remote merge' Thus, monitors and speakers were hubbed in IEC warehouses located in England and Sweden and in a Walsh Western warehouse located in Holland[5] At these locations the peripherals were merged with the system for further distribution

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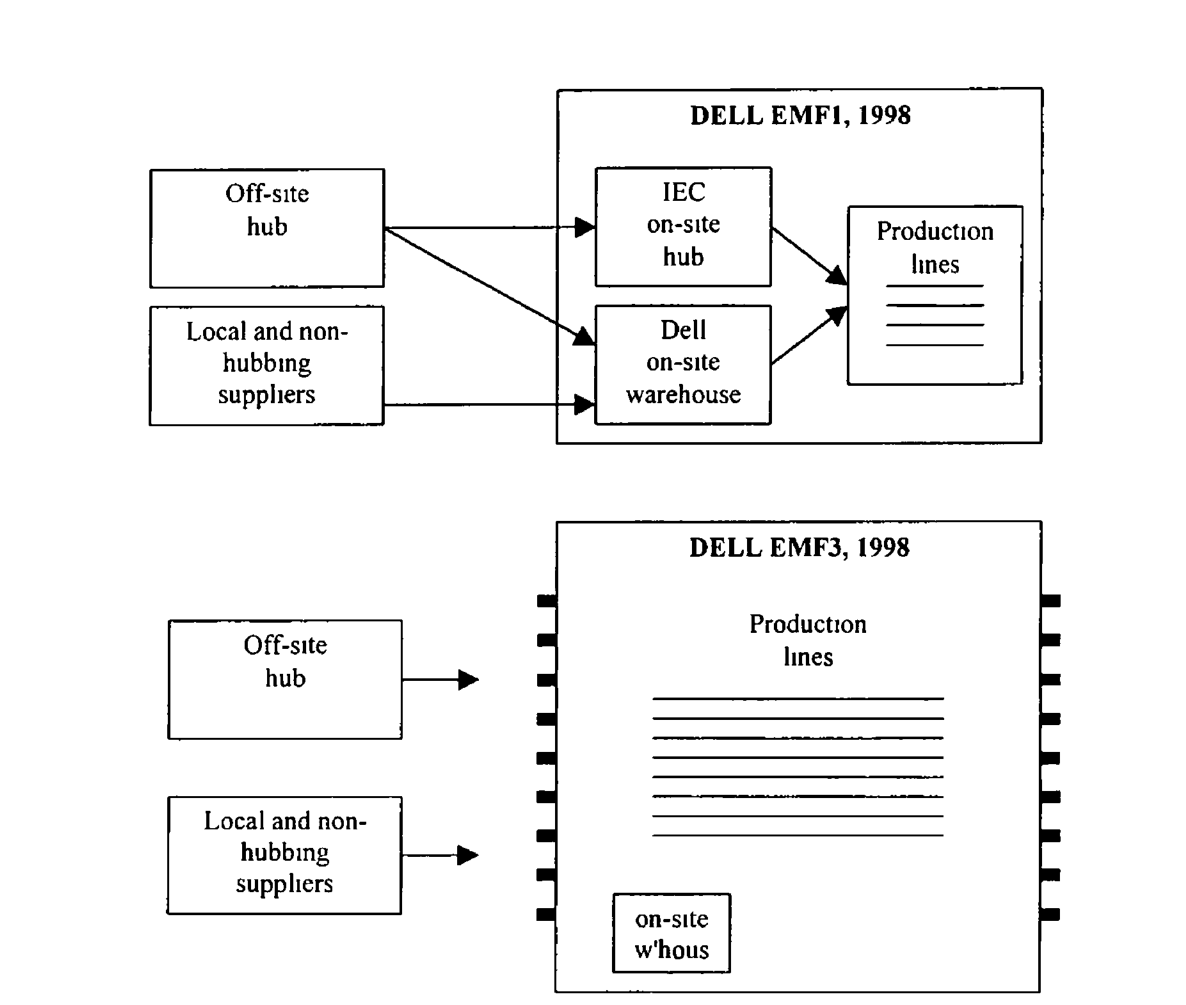
[3] Furthermore, once-off items, bought to fulfil a special customer request, were not hubbed either Finally, some c-class items, e g printed metal labels manufactured in Dublin, were stocked as Dell inventory as well

[4] Logitech had operated a mouse manufacturing plant in Cork and used the existing facility as a vendor hub to service its customers in Ireland and the UK However, since 1999 Logitech hubs mice at 3pl providers (Interview information officer, Logitech Cork, February 2001)
Up to the end of 1998, LMS-Beach had a facility in Limerick near Dell to assemble flat-pack server enclosures, manufactured by one of the LMS plants in the USA When it was awarded the Dell contract to supply high volume desk-top enclosures, LMS set up a manufacturing facility in Tullamore, two hours' drive from Dell The Tullamore facility lacked the required warehouse space and LMS started to hub enclosures at its existing facility in Limerick, rather than at one of the main 3pl hubs However, this facility was closed early 1999, from which moment LMS hubbed all its enclosures at the IEC hub (Interview Roche, LMS-Beach, April 2001)

[5] Furthermore, monitors for the South African market were hubbed at Expeditors in Johannesburg

Figure E 1 Dell's inbound logistics pipeline structure



Source Developed by the author on the basis of interviews with O'Donnell and Allen, Dell, October 1999

The local Walsh Western 3pl hub was located two miles from Dell IEC operated a 3pl hub on the other side of Limerick but had just opened a new 3pl hubbing facility next door to Dell's main plant Furthermore, to further reduce the inventories on Dell's books, IEC operated a hub on Dell's premises as well Although the external hubs were located nearby, the manufacturing operation still required (small) inbound buffers at EMF1 However, at EMF1 these buffers were held as vendor owned material at a physical area dedicated to the IEC hub [6] In effect, Dell pulled from the on-site hub directly to the line Dell still needed its own on-site warehouse for non-hubbed items Because of its complexity, and to facilitate an understanding of the pipeline structures at the other focal companies, Dell's inbound logistics pipeline has been graphically presented in Figure E 1

[6] Although vendors had different arrangements with Dell Some parts were pulled from the external hub and buffered as Dell-owned inventory

Although Dell's hubbing strategy was already well established in 1998, the structure of the inbound pipeline and the location of the hubs were still evolving as part of the aim to continuously reduce the dependency on Dell's own warehouse (read Dell-owned inventory) In the second half of 1999 Dell opened a new manufacturing facility EMF3 The lay-out of EMF3, with 40 in-bound and 40 out-bound bays, virtually eliminated the need for an on-site warehouse Materials from the external hubs and local suppliers arrived in containers at the unloading bays These containers basically functioned as hubs, while the yard provided space for extra trucks and, thus, extra hubbing capacity Dell only owned the inventories from the moment it pulled material from the containers – directly to the production lines [7] At the end of the assembly process material was loaded directly into the containers for distribution A relatively small on-site warehouse was used to store items like microprocessors and other parts that required secure warehousing

Gateway

Gateway's inbound logistics strategy was to minimise the inventories by requesting local suppliers or supply-chain-management companies to deliver on a frequent basis and hub all imported inventories At the time the first interviews were conducted, in 1998, the strategy was nearly fully implemented Thus nearly all imported components were hubbed The exceptions were Intel processors and motherboards, integrated portable base units, heat sinks and a number of low volume OEM items, such as Zip drives and some PC-cards Even the internal cables, manufactured by Keytech in Ireland, were hubbed[8]

Packaging was printed on a true JIT basis in Dublin and supplied three times a day, directly to the production floor Similarly, low-volume keyboard models (i e non-English language) were printed on a true JIT basis in Limerick and delivered on a daily basis Screws and fastenings etc were delivered on a *kan-ban* basis by QEF in Cork, a turnkey supply-chain-manager who bought and held stocks for Gateway In 1998, Gateway still assembled its own accessory kits on-site The supply chain for most of the media was managed by Modus Media, who shrink-wrapped the CD-ROMs and documentation in Kildare[9] and delivered on a frequent basis directly to the Gateway facilities BG Turnkey in Dublin bought and managed the supply chain of Microsoft mice At the time of the second interview Gateway was in the process of outsourcing the kitting of the accessory boxes to Modus Media, thereby further reducing its component inventory levels

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[7] One of the gains was that Dell no longer needed to own the final buffers in the supply-chain involving local suppliers Obviously, this situation could also be reached if local suppliers hubbed at IEC, as was the case with LMS-Beach However, this was an expensive solution for local suppliers, and indirectly for Dell as well Other local suppliers, such as Foxteq in Mullingar (a new local supplier since 2000), supplied directly to Dell, and the inventory in the trucks was vendor owned (Interview McCann, Foxteq, April 2001)

[8] Shortly after the first interviews, in 1999, Keytech started to line-feed cables on a *kan-ban* basis, directly from its own facilities

[9] Documentation was printed by Modus Media in Dublin However, Modus Media sourced all CD-ROMs from third parties

In principle suppliers were free to choose between two main 3pl hubs, IEC and Walsh Western Both 3pl providers operated warehouses near Gateway However, Gateway preferred to consolidate the hubbed inventories, and in 1998 nearly all inbound material was stored at the IEC hub, located at 10 minutes drive from the Gateway plant The few exceptions were Lite-on/Maxiswitch with a hub in Limerick (for high volume keyboard models), Philips (for CD-RW drives) and Plextor (for small amounts of hard disk drives) with hubs in Holland, Thompson Litho with a small vendor hub (for a small amount of media) near Gateway, and 3-Com, who hubbed network cards at Walsh Western Finally, some peripherals, such as monitors, printers, cameras and joy sticks were hubbed at IEC in Dublin as well as at an IEC facility in Wales, for outbound pipeline merge As regards the turnkey supply-chain-managers, Modus Media supplied directly from Kildare, about one hours drive from Gateway[10] BG Turnkey was located at the same industrial estate as Gateway and QEF operated out of Cork

Apple

At the time the first interview was conducted in November 1998, Apple was in the process of re-organising its inbound logistics Apple's inbound logistics strategy was to get all suppliers to hub near Apple, including companies that supplied printed labels and c-class items, like screws The contents of the country kits was to be managed by supply-chain-managers on a turnkey basis and to be kitted and delivered on a JIT basis Packaging was to be supplied direct, on a true JIT basis

In November 1998, Apple's hubbing strategy was already well in place Virtually all material was hubbed near Apple, including enclosures manufactured in Ireland, and microprocessors imported from the USA The supply chains of the content of the country kits was managed by two local supply-chain-managers, BG Turnkey and Walsh Western, who bought and stocked the components on a turnkey basis and also took care of the kitting Only hard-disk drives, configured by Quantum in Ireland, and c-class items such as screws were still supplied direct and held as Apple-owned inventory But even Quantum was requested to hold inventory of generic disks at its facility in Dundalk

At the time Apple was still using a number of 3pl and vendor hubs, nearly all located in Cork City The main hubs were those of BG Turnkey[11], co-located on the same industrial estate, and IEC, located a few miles from Apple Logitech operated its own hub in Cork and enclosures manufactured by SSS in Singapore were hubbed at Tech-source in Cork, who also carried out small value adding activities Alps was located in Millstreet, 50 km from Cork City, where it localised less current keyboard models but also hubbed high-volume keyboard models, to be supplied to the kitters Monitors were all hubbed at a 3pl provider at Schiphol Airport in Holland from where they were distributed directly to the customer

[10] From Q4, 1999, Modus Media started supplying complete country kits from a facility located a few minutes drive from Gateway

[11] Apart from its media and kitting business, BG Turnkey in Cork provided a hubbing service for Apple material as well

However, this was still not considered the optimal solution and Apple was in the process of restructuring the inbound pipeline "All hubs were in Cork, but even then we found that that was not good enough Five miles is limiting our ability to deplete on our inventory, and we need to tightly manage that" (Interview Ruddy, Apple, September 1999) At the time the second interviews were conducted, in 1999, Apple was in the process of consolidating all inbound inventories into an on-site 'super hub', managed by Walsh Western Thus, SSS, Logitech, and Quantum were now hubbing at 3pl as well Furthermore, Apple had consolidated all kitting activities at Walsh Western Finally, Alps no longer localised keyboards in Millstreet, but hubbed these at Walsh Western, who also took care of the key-cap printing of low-volume models

Intel

Intel aimed to reduce the inbound inventories at its European Site for System Manufacturing (ESSM) by requesting suppliers to hub at a single 3pl hub, or by sourcing items on a turnkey basis from local supply-chain-managers

In 1998 the strategy was already fully implemented The components for the country kits (mouse, media, power cord, and in some cases the keyboard), were bought and stocked by BG Turnkey and kitted and delivered on a nearly true JIT basis to Intel's outbound logistics centre Screws and other c-class items were supplied on a *kan-ban* basis by another turnkey supply-chain-manager Mac-B Nearly all other inputs for the system assembly line and the PCB assembly line – including some components manufactured in Ireland[12] – were hubbed at a single Walsh Western 3pl hub The main exception was enclosures, imported from the USA and Scotland These were still collected by Intel's freight partners and stored at Intel as Intel-owned inventory Obviously, Intel microprocessors and Intel motherboards involved intra company transactions and did not need to be hubbed but were stored at the relatively small on-site warehouse

As regards location, the main Walsh Western hub as well as BG Turnkey's facility were located at 20 minutes drive from Intel in Dublin The only vendor hub was the Alps facility in Millstreet, where high-volume keyboard models were hubbed[13]

AST-Samsung

AST aimed to minimise the inbound inventories by requesting local suppliers to produce and supply on a very frequent basis and by making non-local suppliers hub material near the AST plant Furthermore, AST tried to promote delivery directly to the production lines, a system referred to by AST as 'pay-by-consumption'

[12] Hard disk drives configured by Quantum in Dundalk, some of the power cords, other cables and interconnect material from Molex in Shannon, plastic parts, metal parts from Southborough in Dublin

[13] Part of the keyboards were sourced and kitted by BG Turnkey in Dublin However, some of Intel's customers required the keyboard to be integrated in the system box For these orders Intel sourced part of its keyboard requirements direct from Alps in Millstreet

Much of this strategy had already been implemented in April 1999 Thus, the Irish suppliers of enclosures (Dublin), low volume keyboard models (Dundalk) and packaging material (Limerick) were all delivering on a very frequent basis, directly from their own manufacturing premises to AST's facility – in the case of packaging directly to the manufacturing lines The content of the accessory kits was supplied on a turnkey basis by BG Turnkey – kitted on a nearly true JIT basis, and delivered directly to AST's production lines Screws and other c-class items were delivered by QEF, another turnkey supply-chain-manager, using a *kan-ban* system Nearly all other core components were hubbed The main exceptions were Intel microprocessors and motherboards[14], and some OEM supplies such as modems and network cards Portable enclosures, supplied by Samsung Korea, involved intra-firm transactions and did not need to be hubbed They were stored in AST's on-site warehouse

AST tried to consolidate the hubbed materials at two 3pl providers, an IEC warehouse located at the Dock Road in Limerick and a Raindeer warehouse located in Shannon, 20 minutes drive from AST AST dealt with these two 3pl hubs because they had arranged communication systems regarding the material in the hubs, and the two 3pls provided reports on a daily basis In most cases the vendor was free to choose between these two hubs BG Turnkey managed the supply chain of country kits from a facility on the same industrial estate and QEF managed the supply chain of screws from its facility in Cork

In 1998, most material was still pulled from IEC or Raindeer into AST's on-site warehouse However, AST was in the process of shifting the point where goods were changing title forward in the pipeline Thus, most of the hard disk drives were already delivered directly to the production lines, the point-of-consumption, leading to very low inventories on AST's books

IBM

At the time the first interviews were conducted in 1999, IBM was in the process of reorganising its inbound logistics The overall inbound pipeline strategy was to reduce the inbound inventories on IBM's books by making 'local' manufacturers deliver on a frequent basis directly to IBM and by requiring 'non-local' suppliers to hub In effect, IBM aimed "to hub everything that was not affected by size constraints" (Interview Nugent, IBM, July 1999) What was considered 'local' really depended on the service levels required "If the service level is four hours, than local means Scotland If it is 24 hours, than it means Ireland also" (*Ibid*)

At the time the first interviews were conducted, in February 1999, IBM had already made great progress in implementing the strategy Nearly all material inputs were either manufactured locally, hubbed locally, or supplied on a turnkey basis by local supply-chain-managers Thus, the enclosures, low volume keyboard models and packaging, manufactured or printed in Scotland, and heat sinks, manufactured in England, were supplied on a very frequent basis directly from the suppliers' manufacturing premises to

[14] Other motherboards, supplied by BCM/JVC and imported from Taiwan, were hubbed

IBM's facılıty – ın the case of packagıng dırectly to the manufacturıng lınes However, even some of the local manufacturers were requested to hold specıfied mınımum levels of fınıshed goods at theır own premıses The components for the country kıts (typıcally documentatıon, CD-ROM, power cord, and, ın some cases, the mouse, the keyboard and speakers)[15] were bought/prınted[16] and stored by Modus Medıa, kıtted ın a JIT envıronment and delıvered dırectly to the productıon lınes, usıng a *kan-ban* system Sımılarly, NABS managed the supply chaın of screws and other c-class ıtems on a turnkey basıs and delıvered usıng a *kan-ban* system

Many of the other components were already hubbed locally, ıncludıng some ıtems manufactured or configured ın England (motherboards from Celestıca) and Ireland (hard dısc drıves from Quantum and connectors from Molex) The ımported ıtems that were stıll sent dırect, and stored as IBM owned ınventory, ıncluded some of the portable bases and dockıng statıons from Japan, some of the motherboards from the USA and the Far East, specıalısed power supplıes from Italy, flat panel monıtors from the Far East, some of the expansıon cards, some optıons such as dıgıtal cameras, lamınated boards, passıve components, Intel processors and some of the other semıconductors [17] In most cases the reason for not hubbıng a partıcular ıtem was that IBM sımply had not had the tıme to change the arrangement or that the volumes were very low, as ın the case of optıons such as dıgıtal cameras By the end of 1999, all portable bases, dockıng statıons, motherboards, flat panel monıtors, most optıons and most expansıon cards were hubbed as well (Intervıew Harry Stanton, IBM, Aprıl 2001)

IBM exerted no partıcular pressure on theır supplıers to use partıcular hubs and receıved product through varıous 3pl provıders or vendor owned hubs "We don't force our supplıers to use any one hub You can't force the supplıers to use a partıcular hub But we have a range of hubs that we have avaılable and we try to encourage our supplıers to use them " (Intervıew Stanton, IBM, July 1999)

Thus IBM receıved materıal vıa several 3pl provıders, ınter alıa, IEC and Nıppon Express, but the maın hubs were the two facılıtıes of Express Cargo Forwardıng (ECF – the ınternatıonal dıvısıon of IEC) near Paısley aırport In order to further reduce ınbound ınventory levels on ıts own books, IBM had converted part of ıts on-sıte warehouse ınto a facılıty for holdıng 'vendor consıgned ınventory' The supplıers owned the ınventory and IBM charged a mınımal rental for the facılıty It was effectıvely a hub, although ıt was managed by IBM Furthermore, the on-sıte hub dıd not ınvolve 'bırth-to-death' hubbıng – IBM was not ınvolved ın the ınbound freıght and custom formalıtıes There was no rule as to whıch components were to be stored ın the on-sıte hub, but the on-sıte hub offered some clear advantages for IBM "If we could have every supplıer delıver everythıng to that facılıty and have ıt all owned by the supplıer, than we would want to do that Why

[15] The content of the country kıt varıed, dependıng on customer requırements In those cases where components were packed by IBM, IBM pulled from hubs or receıved delıverıes dırectly from the supplıers' local facılıtıes

[16] Modus Medıa dıd ıts own prıntıng Hıgh volume documentatıon was prınted ın Dublın whıle the Scottısh facılıty carrıed out some low volume prıntıng on sıte

[17] In addıtıon, ıtems manufactured at other plants owned or partly owned by IBM (e g some of the hard dısk drıves, monıtors and dısplays) were stocked as IBM ınventory as well

would we want to have hubs 20 km away when we could have it here under the same arrangements? [Furthermore,] it is visible to our system, more live" (Interview Stanton, IBM, July 1999)

Nearly all hubs were located within a 20 miles radius of IBM The main exception concerned monitors that were hubbed in Scotland as well as Amsterdam, from where they were distributed directly to the customer Alps hubbed high-volume keyboard models in Cork, Ireland NABS and Modus Media were located close to IBM, respectively in Greenock and Cumbernauld

Compaq

Compaq's inbound logistics strategy was to minimise its inbound inventories by having the local suppliers of bulk parts deliver on a very frequent basis and by getting "as much as possible [of the other material] vendor hubbed in Express Cargo Forwarding" (Interview Darragh, Compaq, September 1999)

In 1999, this strategy was already fully implemented and nearly all material was either manufactured locally, hubbed locally or supplied on a turnkey basis by local supply-chain-managers that bought, stocked and kitted material for frequent delivery, directly to the production lines (e g components for some of the country kits by Brands Electronics, who also kitted these components[18], screws and other c-class items by TR Fastenings) The exceptions were Intel processors, and highly specialised or unique parts used in the manufacture of high-end computer systems[19] Thus, even motherboards produced in Scotland, some monitors assembled in Wales and England and hard disk drives configured by Quantum in Ireland were 3pl hubbed as well

As regards the location of the hubs, Compaq aimed to consolidate as much as possible of its inbound inventory into one hub Up until early 1999, material had been spread over two ECF 3pl hubs located near Paisley airport – within 30 minutes drive from Compaq However at the time the first interviews were conducted most hubbed inventory was consolidated at a new ECF hub in Linwood – 15 minutes drive from Compaq NMB hubbed high volume keyboard models at Inchinnan Components for some of the country kits were kept at Brands Electronics in Greenock for kitting on a true JIT basis Brands also assembled the low-volume server enclosures manufactured in the USA and effectively functioned as a hub for these products [20] Finally, TR Fastenings conducted 'bread-runs' with screws and other c-class items, stored at a warehouse in East Kilbride

[18] However, most of the country kits were kitted by Compaq Where this was the case, the components were pulled from the local media suppliers and the 3pl hub

[19] Furthermore, in February 1999, Compaq received some high-end motherboards from its sister-plant in Singapore Since this involved intra-firm transactions these boards were not hubbed By the time of the second interview, in September 1999, the manufacture of these boards had been outsourced and the boards were hubbed as well

[20] It is possible to consider Brands as a local manufacturer However, they were effectively hubbing finished stamped metal components on behalf of two USA suppliers, who contracted Brands to assemble the product so as to save on transport costs

All these facilities were located within 30 minutes drive from Compaq Finally, monitors and options were hubbed at the ECF hub in Linwood, as well as ECF hubs in England and Holland The latter facilities functioned as hubs for Compaq's regional distribution centres

Since 1999, Compaq has again restructured its inbound pipelines in order to further reduce the inventories on its books In 1999 Compaq pulled from the ECF hub to replenish minimal buffer levels (two days worth of material) at its on-site hub on a 'min-max' basis In April 2001 this changed to a schedule-based pull system Compaq no longer held minimum buffers at its own plant but every six hours pulled material in for the orders that were on hand

Digital

Although Digital was taken over by Compaq in the first half of 1998, the actual integration of the two companies and the concomitant restructuring of the production networks was not completed until well into 1999 Thus, at the time the first interview was conducted, in February 1999, the inbound pipeline was still very much structured on the basis of a Digital strategy

Digital had been restructuring its inbound pipeline since early 1998, based on a new strategy devised to reduce the inbound inventories on its own books Until early 1998 most components had been supplied on an ex-works basis (i e Digital was responsible for collection from the suppliers' plants and owned the material from the moment of collection) and Digital stocked inbound inventories in its on-site warehouse However, early 1998, Digital decided to require that suppliers had to either have a 'local' manufacturing facility with an ability to deliver within 24 hours, or hub locally

At the time, there was no strategy to consolidate the hubbed inventories into one facility Suppliers were free to arrange their own hubbing facility from where Digital could be supplied within 24 hours Only if they failed to do so were they requested to hub at Digital's main 3pl hubs – the two ECF facilities near Paisly airport

In February 1999, the strategy was already implemented for most components Most components for the system building lines were either manufactured or hubbed at locations from where Digital could be supplied within 24 hours, and most of the components for the board assembly lines were planned to be hubbed in Q1 and Q2 of 1999 However, many suppliers with 'local' manufacturing facilities were requested to hold specified minimum levels of finished goods at their own premises, so Digital could minimise the inventories in its own warehouse The main suppliers that continued to supply direct, on the basis of relatively inflexible purchase orders, were Intel and some of the suppliers of high-end power supplies [21] Screws and other c-class items were supplied

[21] Material supplied by Digital sister-plants needed not to be hubbed and were stored in the on-site warehouse

by Geltron, a turnkey supply-chain-manager, who delivered directly to Digital's production lines, using a *kan-ban* system

The 24-hour service level requirement meant that 'local' manufacturers and hubs could be located at considerable distances Thus, as far as the logistics pipeline was concerned, suppliers with manufacturing facilities in Scotland (supplying enclosures, metal and plastic parts, cables and interconnect, packaging and low volume keyboards) as well as suppliers with facilities in England (power supplies, cables and fans) and Ireland (network components, metal parts and interconnect material), were all considered 'local' and did not need to organise additional hubbing facilities

Similarly, apart from the vendor hubs located in Scotland, (API, Metz[22] and Lite-on for power supplies, Seagate for hard disks, Mitsubishi for monitors, NMB for volume keyboards, Volex and Amphenol for cables)[23], other vendor hubs were located in Ireland (Quantum for hard disk drives, Logitech for mice, Cabletron for network cards, Teradyne for backpanels), England (Fujitsu for hard disk drives), Wales (LG Electronics for monitors) and even Holland (MPL for power supplies, Genicom for printers) Geltron, the turnkey supply-chain-manager operated out of a warehouse in Irvine, at 20 minutes drive from Digital

Thus, until the first quarter of 1999, the requirements of the Ayr facility had been relatively flexible However, by the time of the second interview, in July 1999, the on-going integration of the Ayr facility into the Compaq production network had brought new changes in the structure of the inbound pipeline The Ayr facility had come under strong pressure to bring down the lead-time requirement from 24 hours to two hours Furthermore, "Compaq do not like vendor hubs The problem is that we have a ship signal, it is an electronic signal that goes out and says I want to build this box It is better to send out one signal than three to three different people" (Interview Tyldsley, Digital, July 1999) As a result, by July 1999, nearly all suppliers with manufacturing facilities outside Scotland were hubbing and nearly all hubs were consolidated at ECF in Linwood

Packard Bell-NEC

At the time the first interviews were conducted, in 1999, Packard Bell-NEC aimed to minimise the inbound inventory levels, but hubbing was not a strong element of the strategy

> I do not believe we need a hub At the end of the day you pay for hubbing anyway So I prefer to have my visibility and manage the warehouse I am not a believer in the hub process The only two products that I am interested in vendor hubbing are chassis and monitors (Interview, Rooney, Packard Bell-NEC, September 1999)

[22] Initially, in 1998, Metz even attempted to operate a hubbing facility in Boston but this arrangement failed to live up to the 24-hour delivery requirement

[23] Some of these companies supplied material manufactured at their local facilities However, the same facilities functioned as a hub for products manufactured in other regions

In 1999, nearly all inbound (and outbound) material was routed through a local warehouse run by Walsh Western However, this was merely an arrangement to overcome a lack of on-site warehouse space at Packard Bell Nearly all material in the Walsh Western warehouse was owned by Packard Bell Only the enclosures, imported from Taiwan were hubbed at IEC while high volume keyboard models were vendor hubbed at NMB in Inchinnan Monitors were not hubbed yet, but stocked as Packard-Bell inventory in the local Walsh Western warehouse as well as in a warehouse in England where products were merged for distribution into the retail channel Packaging and low-volume keyboard models were printed on a true JIT basis from facilities in Scotland The supply chain of media was managed on a turnkey basis by Thompson Litho in East Kilbride Thompson Litho bought the CD-ROMs, printed the documentation, shrink-wrapped the material together and delivered it on a daily basis Similarly, the supply chain of cables was managed on a turnkey basis by ECS, who operated a warehouse in the Netherlands

However, in 2000, Packard Bell-NEC had changed its inbound pipeline strategy and aimed to hub most material at ECF in Linwood [24]

Apricot-Mitsubishi

Apricot aimed to minimise the inbound inventories on its books by making local suppliers deliver very frequently and by "hubbing as much as possible" (Carson, Apricot-Mitsubishi, September 1999) However, in 1999 a substantial part of imported material was still not hubbed Thus, Intel microprocessors, Intel motherboards, Intel finished servers, riser cards, most memory, tape back-up/autoloaders, heat sinks, network cards, some of the c-class items and virtually all inputs for the PCB assembly line, were stocked as Apricot-owned inventory and supplied on the basis of specific relatively inflexible purchase orders Furthermore, the enclosures imported from China were hubbed locally, but Apricot-Mitsubishi owned the in-transit inventory [25] The reason for not hubbing was partly explained by the high Intel-content of the supplies -- Intel did not hub Other items were not hubbed because of the limited volumes required by Apricot "We tend only to hub the major parts, we wouldn't hub some cable harness or screws, because our volumes don't warrant the need to do that" (Carson, Apricot, February 1999)

Most other components were hubbed, including packaging, manufactured in Glasgow Volex (cables)[26] and Tatung (monitors) supplied on a relatively frequent basis directly from their own facilities in England but were committed to hold agreed minimum

[24] This information was provided during an introductory telephone conversation for a third interview with staff at Packard Bell-NEC However, the interview never developed and detailed information regarding the developments in the pipeline structures was not obtained

[25] This was a particular arrangement that allowed Apricot to keep control over the transport of these enclosures and thus have a stronger guarantee that enclosures would arrive on time However, the moment enclosures arrived in Scotland they were placed in the hub and the suppliers owned the inventory

[26] Some of the interconnect material supplied by Volex was manufactured in England Other material was manufactured at sister plants in other regions and hubbed at the Volex facility in England

inventory levels for Apricot NMB localised and supplied low-volume keyboard models on a nearly true JIT basis Finally, the supply chains of media were managed on a turnkey basis by Sykes and Thompson Litho Both companies bought CD-ROMs, printed documentation in-house, shrink-wrapped the material and supplied Apricot on a nearly true JIT basis

Apricot did not aim to consolidate the hubbed inventories The majority of suppliers made their own hubbing arrangements, either at their own facilities or at a 3pl provider "We have not followed Compaq and some other companies that have set up a single hub for all their suppliers it does cost money whatever anyone says We did believe that the hubbing process was the correct way to go, however we choose to do that with each of our suppliers and use their premises as the hub" (Interview, Carson, Apricot, February 1999) However, for suppliers that were unable to do so, Apricot had contracted Fife Warehousing, a local warehousing group, to operate a common hub

The Fife Warehousing hub was located at five miles from the plant The information regarding the location of the other hubs is incomplete, but no hubs were located near Apricot-Mitsubishi in Glenrothes Most hubs were located in Glasgow, 75 km from Glenrothes or even further in Scotland, England and Ireland [27] Mitsubishi monitors were hubbed at Mitsubishi's warehouse near London, from where the monitors were shipped direct to the customer The monitors manufactured and stocked at Tatung in the North of England were still merged at Apricot in Scotland [28]

Sun Microsystems

Sun strongly focussed on minimising inbound pipeline inventories One of the strategies towards this end was to use regional suppliers (where it made sense from a total cost perspective) that could supply on a very frequent basis As regards the imported material, to early 1999, Sun did not operate a hubbing system but still had most material collected from its suppliers (free-on-board) and stocked it as Sun-owned inventory However, at the time the first interviews were conducted, in February and July 1999, Sun was in a transition phase "I have been part of the world-wide supply chain strategy team for the last year The strategy is all about hubs, supplier-owned inventory, supplier-owned freight into manufacturing The only time we want to own inventory is when it goes on the production line So we will have less of a Sun-owned inventory solution" (Interview Mayer, Sun, July 1999)

From an implementation point of view, in the first half of 1999 the strategy was still in the very early stages As regards regionally manufactured materials, such as enclosures and motherboards from Scotland and England and microprocessor modules from

[27] NMB hubbed high volume keyboard models at its facility in Inchinnan, Scotland Volex hubbed at its facilities in Cumbernauld and Manchester Logitech hubbed in Cork, Ireland On the other hand, the hard disk drives configured by Quantum in Ireland were hubbed in Glasgow

[28] Apricot pulled monitors from Telford to the facility in Glenrothes where they were merged with the system However, Apricot was in the process of arranging to have the monitors merged with the systems in Telford for further distribution

England, Sun already received material on a very frequent basis However, even some of the regional manufacturers were requested to hold specified minimum levels of finished goods at their own premises and, in case of some of the regional motherboard suppliers, buffers were kept both at the suppliers and at Sun's warehouses

Most items manufactured in other regions were still collected by Sun's freight partners from the suppliers' facilities – on a free-on-board basis The only items hubbed were most hard disk drives, storage tapes, memory, server racks and most of the monitors The supply chain of screws, fasteners, internal cables, labels, and packaging were managed on a turnkey basis by BG Turnkey who supplied these materials directly to the production lines on a daily basis or even more frequently BG Turnkey also managed the supply chains for the content of generic ship kits and language specific country kits, kitted the material and delivered the kits to the production lines in Sun's manufacturing plant in Scotland or to Sun's distribution centre in Holland However, kitting did not take place on a true JIT basis Sun was committed to hold specified minimum levels of finished kits at its own premises By the time of the final interview, in April 2001, Sun had fully implemented the strategy By then Sun kept no significant inventories of regionally manufactured enclosures and motherboards and nearly all imported material was hubbed

In 1999, Sun did not aim to consolidate the hubbed inventories Sun did lease an off-site warehouse from Frans Maas, located in Livingston, 20 minutes drive from the plant However, this warehouse was only in use because of a shortage of space on-site and basically functioned as an extension of the on-site warehouse The strategy was to have the suppliers own and select hubs "The big suppliers select the hub because they service many other suppliers and for smaller suppliers we would offer to set up the hub or introduce them to ECF or Frans Maas" (Interview Mayer, Sun, July 1999)

As regards location, in principle all hubs had to be able to deliver within two to four hours of the pull signal However, at least in 1999, this rule was applied flexibly Seagate operated its own hub in Irvine, Scotland and Hewlett Packard was requested to hub storage tapes at Frans Maas because it could not live up to the two to four hours service requirement from its Bristol facilities However, Quantum hubbed its drives at its facilities in Ireland and Samsung hubbed memory at its distribution centre near London The supply-chain-manager, BG Turnkey, supplied cables, screws, c-class items and ship kits from a facility in Livingston – 20 minutes drive from Sun Partly driven by fiscal reasons, Sun distributed all its product from a distribution centre at Montfoort, The Netherlands Many supplies, notably some of the monitors and other peripherals, were therefore stored or merged at this distribution centre, rather than in Scotland At the time, all inventory stocked at this distribution centre was on Sun's books However the plan was to hub all this material, either at the distribution centre or at vendor hubs Sony monitors were already vendor hubbed in Rotterdam – at 30 minutes drive from Sun BG Turnkey kitted and hubbed the country kits at a facility in Apeldoorn – 30 minutes from Sun

By the time the last interview was conducted, in 2001, there was a clear strategy to consolidate the hubs and many suppliers were now hubbing at Frans Maas in Scotland

Furthermore, Sun aimed to transfer the off-site (leased) warehouse into a proper 3pl hub where suppliers would relate directly to Frans Maas and Sun would be freed from the warehouse as an overhead

APPENDIX F KEY LOGISTICS DATA ON INDIVIDUAL COMPANIES

Table F 1 Target inbound inventory levels by material input

	Dell	*Gateway*	*Apple*	*Intel*	*AST*	*IBM*	*Compaq*	*Digital*	*Packard*	*Apricot*	*Sun*	average*
Material Inputs Far East and Americas												
microprocessors	5	5	5	n d	3	3	3	n d	<10	2	5	4
flat panel monitors	n a	n a	n a	n a	n a	5	n a	n a	n a	n a	5	5
memory	10	10	5	n d	n d	10	10	5	<10	5	5	8
LCD displays	10	int	5	n a	int	5	10	n a	n a	n a	n a	8
server racks	10	10	n a	n a	n a	10	10	n a	n a	5	5	8
tape back-up/ autoloaders	10	10	n a	n a	n a	10	n a	10	n a	5+sup	5	9
modem/network cards	10	10	10	n a	n d	5 or 10	10	10	10	5+sup	5	9
sound/video/graphics cards	10	10	10	n d	n d	5 or 10	10	10	10	5+sup	5	9
AC adapter	10	int	n d	n a	int	5 or 10	10	n a	n a	n a	n a	9
motherboards/backpanels	10	10	10	on-site	n d	10	10	10	10	5	int	9
heat sinks	10	10	10	n a	n a	10	10	10	n d	n a	5	9
enclosures	10	10	10	n d	n a	10	10	10	10	5	n a	9
power supplies	10	10	10	n d	int	10	10	10	10	int	5	9
hard disk drives	10	10	10	n d	n d	10	10	10	10	10	5	9
floppy drive	10	10	10	n d	n d	10	10	10	10	10	5	9
CD ROM drive	10	10	10	n a	n d	10	10	10	10	10	5	9
CRT monitors	10	10	5	n d	n d	10	10	10	10	10	10	9
enclosures for portables	n a	n a	10	n a	n a	10	10	n a	n a	n a	n a	10
small plastic/metal parts	n a	n a	n a	n a	n a	10	n a	10	n a	n a	int	10
riser cards	n d	n d	n d	n d	n d	10	int	10	n d	5	n d	10
cooling fans	10	10	int	n d	n a	int	10	10	int	int	int	10
CD RW drive	n a	10	n a	n a	n d	10	10	n a	10	n a	n a	10
DVD drive	10	10	10	n a	n a	10	10	n a	10	n a	n a	10
combo drive	10	int	n a	n a	n a	10	n a	n a	n a	n a	n a	10
zip drive	10	10	10	n a	n a	n d	n a	n a	10	n a	n a	10
docking stations	on-site	10	n a	n a	n a	10	on-site	n a	n a	n a	n a	10
partly integrated portables	10	10	n a	n a	n d	n a	n a	n a	n a	n a	n a	10
high volume keyboards	10	10	10	n d	n d	10	10	n d	n d	10	int	10
joysticks	n d	10	n a	n a	n d	10	n a	n a	n a	n a	n a	10

	Dell	Gateway	Apple	Intel	AST	IBM	Compaq	Digital	Packard	Apricot	Sun	average*
microphone	n d	n d	10	n a	n d	10	n d	n a	10	n a	int	10
scanner	10	10	n a	n a	n a	10	n a	n a	10	n a	n a	10
printers	10	10	10	n a	n a	n a	n a	10	10	n a	n a	10
battery for portable	20	int	10	n a	int	10	10	n a	n a	n a	n a	13
speakers	10	n d	int	n a	n d	10	20	int	10	int	n a	13
mice	20	n d	10	n d	n d	10	20	n d	10	10	int	13
power cables	20	n a	>20	n a	int	10	20	10	n d	10	int	14
other cables	20	n a	>20	n a	n d	10	20	10	n d	int	>5	15
screws and fasteners	large	large	40	n d	n d	>40	20	large	int	60	20	35
digital camera	n a	n d	n a	n a	n a	n d	n a	n a	n a	n a	n a	n d
Material Inputs Europe												
power supplies	n a	n a	n a	n a	n a	4	n a	small or 10	n a	n a	5	5
tape back up/ autoloaders	n a	n a	n a	n a	n a	n a	10	n a	n a	n a	5	8
hard disk drives	n a	10	n a	n a	n a	4	10	n a	n a	n a	n a	8
memory	10	10	n a	n a	n a	n a	n a	5	n a	n a	n a	8
CRT monitors	10	n a	n a	n a	n a	10	n a	n a	n a	n a	5	8
enclosures for portables	n a	n a	n a	n a	n a	10	n a	n a	n a	n a	n a	10
motherboards/backpanels	n a	n a	n a	n a	n a	n a	10	n a	n a	n a	n a	10
cooling fans	n a	n a	n a	n a	n a	n a	n a	10	n a	n a	n a	10
sound/video/graphics cards	n a	n a	n a	n a	n a	n a	10	n a	n a	n a	n a	10
printers	10	n a	n a	n a	n a	n a	n a	n a	n a	n a	n a	10
other cables	n a	n a	n a	n a	n a	n a	n a	10	n a	n a	n a	10
Material inputs Ireland and UK												
packaging	1	1	1	small	small	small	small	small	1	2	2	2
low volume keyboards	small	2	1	small	small	small	small	small	small	small	int	2
country kits	n a	n a	1	small	small	small	small	n a	n a	n a	5	2
CD ROMs (wrapped)	1	15	int	int	int	small	1	1or 5	small	2	int	4
printed media (wrapped)	1	15	int	int	int	small	1	1or 5	small	2	int	4
heat sinks	n a	n a	n a	n a	n a	5	n a	n a	n a	5+sup	n a	5

	Dell	Gateway	Apple	Intel	AST	IBM	Compaq	Digital	Packard	Apricot	Sun	average*
enclosures	10	n a	4	n d	2	10	2 (8g)	5 (5g)	n a	n a	5	5
hard disk drives	5	5(5g)	2(5g)	n d	n d	n d	10	small(8g)	n a	10	5	6
server racks	10	n a	n a	n a	n a	n a	2 (8g)	5 (5g)	n a	n a	n a	6
small plastic/metal parts	10	n a	10	n d	n a	10	10	5	n a	n a	n a	9
modem/network cards	10	10	n a	on-site	n a	n a	10	10	n a	5+sup	5	9
motherboards/backpanels	10	n a	n a	n a	n d	10	10	int	n a	n a	5 or 10	9
power supplies	n a	n a	n a	n a	n a	n a	n a	10	n a	n a	n a	10
CRT monitors	n a	10	n a	n d	n a	10	10	n a	n a	10	n a	10
printers	n a	10	n a	n a	n a	n a	n a	n a	10	n a	n a	10
flexcirquit	n a	n a	n a	n a	n a	n a	n a	10	n a	n a	n a	10
printed labels	10+sup	n d	10	n d	n a	n a	10	n a	n d	5+sup	20	13
power cables	20	10	n d	int	int	10	20	10	n a	10	int	13
other cables	20	>10	n a	n d	n d	10	n d	10	n a	n a	>5	13
cooling fans	n a	n a	n a	n a	n a	n a	n a	int	n a	n a	n a	int
Inputs PCB assembly												
etched circuit boards non-regional	n a	n a	n a	n d	n a	5	n d	n d	n a	n a	n a	5
etched circuit boards UK	n a	n a	n a	n a	n a	n a	n a	n a	n a	5	n a	5
other semiconductors	n a	n a	n a	n d	n a	5 or 10	n d	10	n a	5+sup	n a	9
capacitors/resistors	n a	n a	n a	n d	n a	10+sup	10+sup	5	n a	5+sup	n a	
interconnect material	n a	n a	n a	n d	n a	10	n d	n d	n a	5+sup	n a	10

Key

n a = not applicable

n d = no data

int = input comes integrated with other component

g = buffer of generic (unfinished) material held by suppliers

on-site = manufactured by focal company on site

(+sup) = here apart from the inbound inventories stored at the focal companies the supplier kept unstipulated inventories as well - at hub local warehouse or plant

* only precise figures were included in the calculation of average figures The exception was the indication 'small' which was counted as 2 days

Table F 2 Target shipment frequencies by material input (number of days between shipments)

	Dell	Gateway	Apple	Intel	AST	IBM	Compaq	Digital	Packard	Apricot	Sun	average
Material Inputs Far East and Americas												
microprocessors	1	5	2	n d	2	1	2	1	n d	2	1	2
flat panel monitors	n a	n a	n a	n a	n a	5	n a	n a	n a	n a	5	5
memory	1 to 3	5	2 to 5	n d	n d	1	2	3	n d	5	1	3
LCD displays	n d	int	5	n a	int	2	5	n a	n a	n a	n a	4
server racks	5	5	n a	n a	n a	5	5	n a	n a	20	1	7
tape back up/ autoloaders	5	5	n a	n a	n a	5	n a	5	n a	5	5	5
modem/network cards	5 or 10	10	10	n a	n d	5	5	10	n d	n d	1	7
sound/video/graphics cards	5 or 10	5	10	n d	n d	5	5	10	n d	n d	1	6
AC adapter	5	int	n d	n a	int	5	5	n a	n a	n a	n a	5
motherboards/backpanels	5	5	5	on-site	n d	1 to 2	2	10	n d	20	int	7
heat sinks	10	10	10	n a	n a	5	5	10	n d	n a	2	7
enclosures	5	5	10	n d	n a	5	5	10	n d	5 or 10	n a	7
power supplies	10	5	10	n d	int	5	5	10 or 3	n d	int	2	6
hard disk drives	5	5	5	n d	n d	n d	5	n d	n d	5	5	5
floppy drive	5	5	5 or 10	n d	n d	5	5	n d	n d	5	3	5
CD ROM drive	5	5	10	n a	n d	5	5	5	n d	5	3	5
CRT monitors	5	5	5	n d	n d	5	5	5	n d	5	5	5
enclosures for portables	n a	n a	10	n a	n a	5	5	n a	n a	n a	n a	7
small plastic/metal parts	n a	n a	n a	n a	n a	4	n a	5	n a	n a	int	5
riser cards	n d	n d	n d	n d	n d	2	int	5	n d	20	n d	9
cooling fans	10	10	int	n d	n a	int	5	10	int	int	int	9
CD RW drive	n a	5	n a	n a	n d	5	5	n a	n d	n a	n a	5
DVD drive	5	5	10	n a	n a	5	5	n a	n d	n a	n a	6
combo drive	5	int	n a	n a	n a	5	n a	n a	n a	n a	n a	5
zip drive	5	5	5	n a	n a	n d	n a	n a	n d	n a	n a	5
docking stations	on site	5	n a	n a	n a	5	on-site	n a	n a	n a	n a	5
partly integrated portables	2	5	n a	n a	n d	n a	n a	n a	n a	n a	n a	4
high volume keyboards	5	8	10	n d	n d	5	5	n d	n d	5	int	6
joysticks	10	5	n a	n a	n d	5	n a	n a	n a	n a	n a	5
microphone	10	n d	10	n a	n d	5	n d	n a	n d	n a	int	8
scanner	5	5	n a	n a	n a	5	n a	n a	n d	n a	n a	5
printers	5	5	10	n a	n a	n a	n a	5	n d	n a	n a	6
battery for portable	5	int	10	n a	int	5	5	n a	n a	n a	n a	6
speakers	5 or 10	5	int	n a	n d	5	10	int	n d	int	n a	7
mice	n d	n d	10	n d	n d	n d	10	n d	n d	5 or 10	int	9
power cables	n d	n a	20	n a	int	n d	10	10	n d	n d	int	10
other cables	5	n a	20	n a	n d	n d	10	10	n d	int	n d	11
screws and fasteners	n d	n d	20	n d	n d	n d	n d	n d	int	60	n d	40

	Dell	Gateway	Apple	Intel	AST	IBM	Compaq	Digital	Packard	Apricot	Sun	average
digital camera	n a	n d	n a	n a	n a	n d	n a	n a	n a	n a	n a	n d
Material Inputs Europe												
power supplies	n a	n a	n a	n a	n a	bs(2)	n a	2(bc)	n a	n a	2(bc)	2
tape back up/ autoloaders	n a	n a	n a	n a	n a	n a	n d	n a	n a	n a	3(bc)	3
hard disk drives	n a	5(bdh)	n a	n a	n a	3(bc)	3 to 5(bdh)	n a	n a	n a	n a	4
memory	1 to 3(bdh)	5(bdh)	n a	n a	n a	n a	n a	3(bc)	n a	n a	n a	3
CRT monitors	2(bdh)	n a	n a	n a	n a	n d	n a	n a	n a	n a	1(bc)	2
enclosures for portables	n a	n a	n a	n a	n a	2(bdh)	n a	n a	n a	n a	n a	2
motherboards/backpanels	n a	n a	n a	n a	n a	n a	1(bdh)	n a	n a	n a	n a	1
cooling fans	n a	n a	n a	n a	n a	n a	n a	2(bdh)	n a	n a	n a	2
sound/video/graphics cards	n a	n a	n a	n a	n a	n a	5(bdh)	n a	n a	n a	n a	5
printers	5(bdh)	n a	n a	n a	n a	n a	n a	n a	n a	n a	n a	5
other cables	n a	n a	n a	n a	n a	n a	n a	2(bdh)	n a	n a	n a	2
Material inputs Ireland and UK												
packaging	bs(1)	bs(1)	bs(<1)	bs(1)	bs(<1)	bs(<1)	bs(<1)	bs(<1)	bs(<1)	5(bdh)	<1(bdh)	
low volume keyboards	bs(1)	bs(1)	bs(1)	bs(1)	n d	bs(1)	bs(1)	bs(1)	bs(1)	bs(2)	int	
country kits	n a	n a	bs(1)	bs(1)	bs(<1)	bs(1)	bs(1)	n a	n a	n a	bs(1)	
CD ROMs (wrapped)	bs(<1)	bs(1)	bs(1)	int	int	1(bdh) or bs(1)	1(bdh) or bs(1)	1(bc) or bs (1)	bs(1)	bs(1)	int	
printed media (wrapped)	bs(<1)	bs(1)	bs(1)	int	int	1(bdh) or bs(1)	1(bdh) or bs(1)	1(bc) or bs (1)	bs(1)	bs(1)	int	
heat sinks	n a	n a	n a	n a	n a	bs(1)	n a	n a	n a	20(bc/bs)	n a	
enclosures	bs(1)	n a	1(bdh/bs)	n d	bs(1)	bs(1)	bs(<1)	bs(1)	n a	n a	bs(1)	
hard disk drives	n d	bs(1)	bs(1)	n d	n d	n d	2 to 3(bdh)	bs(1)	n a	n d	bs(1)	
server racks	n d	n a	n a	n a	n a	n a	bs(1)	bs(1)	n a	n a	n a	
small plastic/metal parts	bs(1)	n a	n d	n d	n a	3 to 5(bdh or bc)	2(bdh)	1(bc)	n a	n a	n a	
modem/network cards	5 or 10(bdh or bc)	10(bdh)	n a	on-site	n a	n a	5(bdh)	n d	n a	n d	1(hc)	
motherboards/backpanels	2(bdh) bs(2 or 1)	n a	n a	n a	n d	1(bdh)	1(bdh)	int	n a	n a	bs/bc(1)	
power supplies	n a	n a	n a	n a	n a	n a	n a	2(bh)	n a	n a	n a	
CRT monitors	n a	1(bh)	n a	n d	n a	bs(1)	n d	n a	n a	bs(5)	n a	
printers	n a	n d	n a	n a	n a	n a	n a	n a	n d	n a	n a	
flexcirquit	n a	n a	n a	n a	n a	n a	n a	1(bc)	n a	n a	n a	
printed labels	10(bc/bs)	n d	10 (bc/bs)	n d	n a	n a	bs(1)	n a	n d	20(bc)	n d	
power cables	bs(1)	bs(3)	n d	int	int	n d	n d	1(bdh)	n a	bs(5)	int	
other cables	bs(1)	3(bdh)	n a	n d	n d	n d	n d	bs(1)	n a	n a	n d	
cooling fans	n a	n a	n a	n a	n a	n a	n a	int	n a	n a	n a	
Inputs PCB assembly												
etched circuit boards non regional	n a	n a	n a	n d	n a	3(bc)	5 or 10(bc)	n d	n a	n a	n a	

	Dell	Gateway	Apple	Intel	AST	IBM	Compaq	Digital	Packard	Apricot	Sun	average
etched circuit boards UK	n a	n a	n a	n d	n a	n a	n a	n a	n a	5(bc)	n a	
other semiconductors	n a	n a	n a	n d	n a	1 to 3(bc/bdw)	n d	5(bc)	n a	5(bc/bdw)	n a	
capacitors/resistors	n a	n a	n a	n d	n a	n d	n d	2 to 3(bc)	n a	20(bc/bdw)	n a	
interconnect material	n a	n a	n a	n d	n a	n d	n d	n d	n a	n d	n a	

Key

n a = not applicable

n d = no data

int = input comes integrated with other component

on site = manufactured by focal company on site

bs = main buffers are positioned at supplier s plant (which might or might not involve a hubbing arrangement) Figures between brackets represent frequency of shipment from supplier to focal company

bc = main buffers are positioned at customer (focal company) Figures indicate frequency of shipment from supplier s manufacturing facility to focal company

bdh = main buffers are positioned at a detatched local hub (not part of the supplier s plant and not part of the customer s plant) Figures indicate frequency of shipmnet from supplier s plant to hub

bc/bdw = buffers positioned both at the customer and a detatched local warehouse of the supplier (no hubbing arrangement) Figures indicate frequency of shipmnet from supplier s warehouse to customer

Table F 3 Preferred mode of transport by material input

	Dell	Gateway	Apple	Intel	AST	IBM	Compaq	Digital	Packard	Apricot	Sun	typical
Material Inputs Far East and Americas												
microprocessors	p	p	p	n d	p	p	p	p	p	p	p	p
flat panel monitors	n a	n a	n a	n a	n a	n d	n a	n a	n a	n a	p	limited data
memory	p	p	p	n d	p	p	p	p	n d	p	p	p
LCD displays	int	int	s	n a	int	p	s	n a	n a	n a	n a	no typ mode
server racks	s	p	n a	n a	n a	s	s	n a	n a	p	p	no typ mode
tape back-up/ autoloaders	p	p	n a	n a	n a	n d	n a	p	n a	s	p	p
modem/network cards	p	p	p	n a	n d	p	p	p	n d	p	p	p
sound/video/graphics cards	p	p	p	n d	n d	p	p(usa)s(fe)	p	n d	p	p	p
AC adapter	p	int	n d	n a	int	p	p	n a	n a	n a	n a	p
motherboards/ backpanels	p	p	p	on-site	p	p	p	p	n d	p	int	p
heat sinks	n d	s	s	n a	n a	s	s	p	n d	n a	p	s
enclosures	s	s	s	n d	n a	s	s	s	n d	s	n a	s
power supplies	s	s	s	n d	int	s	s	p	n d	int	p	s
hard disk drives	p	p	p	n d	n d	s	s	n d	n d	p	p	p
floppy drive	p	p	s	n d	n d	s	s	n d	n d	s	p	no typ mode
CD ROM drive	p	p	s	n a	n d	n d	s	p	n d	p	p	p
CRT monitors	s	s	s	n d	n d	s	s	s	n d	s	s	s
enclosures for portables	n a	n a	s	n a	n a	s	s	n a	n a	n a	n a	s
small plastic/metal parts	n a	n a	n a	n a	n a	s	n a	p	n a	n a	int	no typ mode
riser cards	n d	n d	n d	n d	n d	p	int	p	n d	p	n d	p
cooling fans	s	s	int	n d	n a	int	s	p	int	int	int	s
CD RW drive	n a	p	n a	n a	n d	n d	s	n a	n d	n a	n a	no typ mode
DVD drive	p	p	p	n a	n a	n d	s	n a	n d	n a	n a	p
combo drive	p	int	n a	n a	n a	n d	n a	n a	n a	n a	n a	limited data
zip drive	p	p	p	n a	n a	n d	n a	n a	n d	n a	n a	p
docking stations	on-site	p	n a	n a	n a	s	on-site	n a	n a	n a	n a	no typ mode
partly integrated portables	p	p	n a	n a	p	n a	n a	n a	n a	n a	n a	p
high volume keyboards	s	s	s	n d	n d	s	s	s	n d	s	int	s
joysticks	s	s	n a	n a	n d	s	n a	n a	n a	n a	n a	s

	Dell	Gateway	Apple	Intel	AST	IBM	Compaq	Digital	Packard	Apricot	Sun	typical
microphone	s	n d	p	n a	n d	s	s	n a	n d	n a	int	s
scanner	s	n d	n a	n a	n a	s	n a	n a	n d	n a	n a	s
printers	s	s	s	n a	n a	n a	n a	s	n d	n a	n a	s
battery for portable	p	int	s	n a	int	s	p	n a	n a	n a	n a	no typ mode
speakers	s	s	int	n a	n d	s	s	int	n d	int	n a	s
mice	n d	n d	p	n d	n d	n d	s	p	n d	p	int	p
power cables	n d	n a	s	n a	int	s	s	s	n d	s	int	s
other cables	n d	n a	s	n a	n d	s	s	p	n d	int	p	no typ mode
screws and fasteners	p	n d	p	n d	n d	p	n d	p	int	n d	n d	p
digital camera	n a	n d	n a	n a	n a	s	n a	n a	n a	n a	n a	limited data
Material Inputs Europe												
power supplies	n a	n a	n a	n a	n a	t	n a	t	n a	n a	t	t
tape back-up/ autoloaders	n a	n a	n a	n a	n a	n a	t	n a	n a	n a	t	t
hard disk drives	n a	t	n a	n a	n a	t	t	n a	n a	n a	n a	t
memory	t	t	n a	n a	n a	n a	n a	t	n a	n a	n a	t
CRT monitors	t	n a	n a	n a	n a	t	n a	n a	n a	n a	t	t
enclosures for portables	n a	n a	n a	n a	n a	t	n a	n a	n a	n a	n a	t
motherboards/backpanels	n a	n a	n a	n a	n a	n a	t	n a	n a	n a	n a	t
cooling fans	n a	n a	n a	n a	n a	n a	n a	t	n a	n a	n a	t
sound/video/graphics cards	n a	n a	n a	n a	n a	n a	t	n a	n a	n a	n a	t
printers	t	n a	n a	n a	n a	n a	n a	n a	n a	n a	n a	t
other cables	n a	n a	n a	n a	n a	n a	n a	t	n a	n a	n a	t
Material inputs Ireland and UK												
packaging	t	t	t	t	t	t	t	t	t	t	t	t
low volume keyboards	t	t	t	t	t	t	t	t	t	t	t	t
country kits	n a	n a	t	t	t	t	t	n a	n a	n a	t	t
CD ROMs (wrapped)	t	t	t	int	int	t	t	t	t	t	t	t
printed media (wrapped)	t	t	t	int	int	t	t	t	t	t	t	t
heat sinks	n a	n a	n a	n a	n a	t	n a	n a	n a	t	n a	t

	Dell	*Gateway*	*Apple*	*Intel*	*AST*	*IBM*	*Compaq*	*Digital*	*Packard*	*Apricot*	*Sun*	*typical*
enclosures	t	n a	t	t	t	t	t	t	n a	n a	t	t
hard disk drives	t	t	t	t	n d	t	t	t	n a	t	t	t
server racks	t	n a	n a	n a	n a	n a	t	t	n a	n a	n a	t
small plastic/metal parts	t	n a	t	t	n a	int	t	t	n a	n a	n a	t
modem/network cards	t	t	n a	on-site	t	n a	t	t	n a	t	t	t
motherboards/backpanels	t	n a	n a	n a	t	t	t	int	n a	n a	t	t
power supplies	n a	n a	n a	n a	n a	n a	n a	t	n a	n a	n a	t
CRT monitors	n a	t	n a	t	n a	t	t	n a	n a	t	n a	t
printers	n a	t	n a	n a	n a	n a	n a	n a	t	n a	n a	t
flexcirquit	n a	n a	n a	n a	n a	n a	n a	t	n a	n a	n a	t
printed labels	t	t	t	t	n a	n a	t	n a	n d	t	t	t
power cables	t	t	t	int	int	t	t	t	n a	t	t	t
other cables	t	t	n a	t	t	t	t	t	n a	n a	t	t
cooling fans	n a	n a	n a	n a	n a	n a	n a	int	n a	n a	n a	t
Inputs PCB assembly												
etched circuit boards non-regional	n a	n a	n a	n d	n a	p	p	p	n a	n a	n a	p
etched circuit boards UK	n a	n a	n a	n a	n a	n a	n a	n a	n a	t	n a	t
other semiconductors	n a	n a	n a	n d	n a	p	p	p	n a	p	n a	p
capacitors/resistors	n a	n a	n a	n d	n a	p	mix	p	n a	mix	n a	p
interconnect material	n a	n a	n a	n d	n a	p	n d	p	n a	mix	n a	p

Key

n a = not applicable

n d = no data

int = input comes integrated with other component

on-site = manufactured by focal company on site

t = truck

s = ship

p = plane