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A great munitions centre

Coventry's armaments and munitions industry 1914-1918

Batchelor, Laurence Anthony

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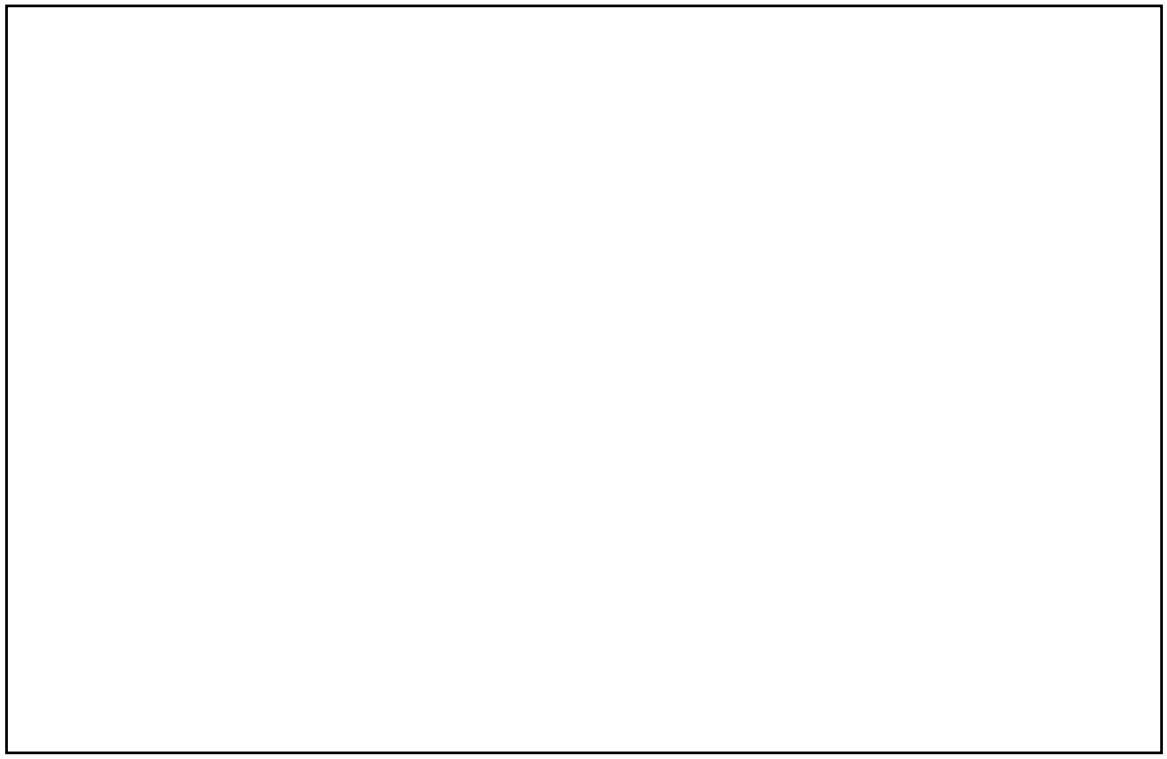
A GREAT MUNITIONS CENTRE: COVENTRY'S ARMAMENTS & MUNITIONS INDUSTRY 1914 – 1918

Laurence Anthony Batchelor



"We see new factories arise; we see aeroplanes in the air. The workshops have been industrial beehives all the time and Coventry has developed as a great munitions centre. The vast number of workmen near the factories at meal times show the force of the workers; but the flurry of activity at night is not as generally observed by the public. It will surprise people some day to learn how greatly Coventry contributed to the output of munitions for both Great Britain and her Allies."[*]

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Department of Geography, Faculty of Business, Environment and Society
Coventry University

[*] The editor writing in the *Coventry Graphic* 17th September 1915 p3 emphasis added.

ABSTRACT

It is now common in the study of concentrations of industry to consider them as local or regional clusters of firms. This stems from a wave of empirical and theoretical research into concentrations of economic activity continuing the earlier work of Alfred Marshall who observed that firms seemed to accrue benefits from concentrating in space and time. By 1914 the city of Coventry was undergoing rapid expansion and embracing a second wave of British industrialisation with its economy comprising a series of clustered light-engineering firms at the heart of cycle, motorcycle and motor vehicle production. During the First World War, the city became transformed into an arsenal of war for four-and-a-half years and contributed greatly to British and Allied armaments and munitions production. Crucially, the research conceptualizes this collection of firms as an evolving armaments and munitions cluster, undergoing rapid expansion and adaptation to meet the demands of the war effort. The research identifies the principal characteristics of no less than 166 factories manufacturing armaments and munitions and 13 support institutions and infrastructure and maps their changing distribution across Coventry between 1914 and 1918. Secondly, the research identifies the type(s) of cluster this wartime economy became and shows the cluster grew from a predominantly nucleated hub-and-spoke cluster to a state anchored/centred cluster and finally to a cluster leading to innovation. Thirdly, the research reveals how under wartime conditions a cluster was able to evolve rapidly from one type to another by demonstrating it was through the Coventry Armaments Output Committee. Finally, these research findings are related to what impact, both positive and negative, a successful WWI armaments and munitions cluster had upon the city's development, suggesting engineering science and inter-firm and inter-governmental co-operation, were two important legacies.

KEYWORDS

Armaments Clusters Coventry Engineering Munitions First World War

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Museum of British Road Transport, Millennium Place, Hales Street, Coventry
Lanchester Library, Coventry University, Gosford Street, Coventry
Modern Records Centre: Warwick University, SE Coventry

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Contents **Page(s)**

List of Figures **Page**

List of Figures (cont.) **Page**

List of Tables **Page**

List of Tables (cont.) **Page**

List of Maps **Page**

Chapter 1: Introduction

This chapter shall outline the nature, scope and aims of the study. First, the chapter will justify why Coventry's engineering sector provides a useful case study. Second, it will show how previous research on the city's engineering sector has been neglected for the years 1914 to 1918. Thirdly the main aim of this study (and the objectives needed to accomplish the research) will be outlined. Lastly, the chapter concludes by outlining the remaining structure of the thesis.

1.1 The usefulness of Coventry as an industrial cluster[1] case study

In the development of regional clusters Coventry can be considered a city that was propelled by a second-wave of industrial activity during the late nineteenth and early twentieth centuries. At that time, it was described as the 'Detroit of England' and was the fastest growing city in Britain shortly before the First World War[2]. The city itself comprised a range of interconnected industrial clusters, including cycle, motorcycle and motorcar manufacturers, machine tool, electrical engineering and component firms. Importantly these were highly inter-dependent and the technologies and markets linking them were similar[3]. With the onset of war this light engineering cluster provides a useful example of an economy which was radically altered and expanded through wartime demands and state intervention.

During the War, the city was an arsenal of munitions production for four and half years and where the Army and Navy spent over £40,500,000 with local manufacturers[4].
In addition to large orders being placed the city's population and urban landscape was radically altered to meet the ever increasing demands placed upon it.

[1] In its simplest form a cluster may be described as a concentration, in time and space, of interrelated firms
[2] Thoms & Donnelly (2000)
[3] Thoms & Donnelly (1987) *Coventry's Industrial Economy, 1880-1980.*
[4] Wilkins (1919) *'Coventry in the Great War 1914-1919'.*

The number of workers engaged in munition manufacture was estimated at 60,000, with 30,000 men and women drafted into the city through the labour exchanges[5]. To house this workforce thousands of new houses were constructed and a scheme of official billeting was instigated across the city. This became inadequate and billeting spread to outlying towns and villages with some 16,000 workers commuting daily into the city during wartime. A new national fuse and filling factory was constructed on the outskirts of the city where over 220 acres of open fields were added to the industrial capacity of the city. So complete was the transformation of the pre-war economy to war-time needs it was later suggested that:

> No other city in this country was so completely absorbed in the production of munitions as was Coventry. The great cities had of course a larger output, but for the completeness of concentration of every tool in the hands of every worker in every workshop to the one end, no other city could show anything approaching Coventry's record.[6]

Despite the significance of the First World War to the city's local economic development it has largely been neglected in previous historiographies. Richardson (1972) and more recently McGrory (2003) both treat this period in the city's industrial development quite fleetingly. Other studies have tended only to examine one aspect of the city's expanding engineering sector spread throughout the course of the twentieth century.[7] These previous studies on the one hand inform the research about particular companies and labour relations, and on the other, provide a window of opportunity as there has been no previous study of Coventry's entire light engineering sector during the twentieth century[8]. This study, therefore, will not only be inherently more holistic, but will also examine exclusively the neglected First World War period in the city's industrial development.

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[5] Ibid
[6] Nowell (1927) '*Coventry and the Great War'*
[7] Britain (1989): machine tool firms; Beaven (1994): automotive component firms; Thoms & Donnelly (1985, 2000): motor car manufacturers, whilst others have addressed the changing aspects of labour within the city, Beasley (undated): women munition workers in Coventry; Hodgkinson (1970): the rise of trade unionism and Carr (1978): engineering workers in Coventry.
[8] There were two exceptions out of c.330 'light' engineering firms that can be considered 'heavy' engineering firms, namely the Coventry Ordnance Works and the Brett's Patent Lifter Company.

1.2 Examining the armaments and munitions industry in Coventry during WWI

Now that the both the usefulness of Coventry as a case study has been established and it was shown how the industrial development of the city between 1914 and 1918 has been neglected, it is timely to propose the aim of this study. The proposed research seeks to conduct an empirical case study examination of firms and support entities[9] involved in armaments and munitions production in Coventry, between the years of 1914 and 1918. Specifically, it wishes to understand the nature of the cluster, how it operated and evolved, and to consider the short and long-term implications this may have had upon the industrial development of the city. The main research aim is:

- To examine the historical geography of Coventry's armament and munitions cluster between 1914 and 1918.

In order to accomplish this aim this study is concerned with completing four objectives:

- To identify the principal characteristics of the companies manufacturing armaments and munitions between 1914 and 1918.
- To map the changing distribution of these companies across Coventry between 1914 and 1918.
- To examine some of the linkages between these firms to establish the type or types of armament and munitions cluster(s) evident in the city at this time.
- To develop an explanation as to why a successful First World War armaments cluster developed in Coventry and add to a broader understanding of the economic, industrial and urban development of the city in the first quarter of the twentieth century.

[9] Including such things as committees, trade associations, social clubs and key infrastructure used by firms

1.3 The remaining structure of the thesis

The thesis will attempt to address these aims and objectives in a number of key stages. First, it will present a review of the various ways in which industrial clusters have been theorised (Chapter 2). Chapter 3 will outline how these theories have informed the research methods used in order to complete the research. Chapter 4 will go on to contextualize the industrial development of the city up to 1914, including the important restructuring and local historical factors that were present in the engineering cluster at the commencement of hostilities.

Chapter 5 will identify the munitions firms operating within the city, what they were producing (and when) and establish some of the mechanisms that these firms relied upon. It will summarize this information in the form of three maps: the early war cluster (August – December 1914), the mid war cluster (Spring 1915 – December 1915), and the late war cluster (January 1916 – November 1918). Chapter 6 will examine in greater detail the nature and role for a selection of firms paying particular attention to the linkages between firms and infrastructure in order to explain what type of cluster(s) armaments and munitions production was in wartime Coventry. Finally, Chapter 7 will account for why a successful armaments cluster emerged and what impact both positive and negative this may have had upon the city for the short and longer-term.

Chapter 2: Industrial Districts and Clusters: Providing a useful Conceptual Framework

Having outlined the need for an investigation of Coventry's First World War armaments and munitions industry this chapter now places the study into the wider context of existing research themes linked to agglomeration studies and in particular the theory of local industrial clusters[11]. According to Wolfe, Davis & Lucas (2005) differences in emphasis and method by a variety of disciplines (especially regional science, economics and geography) make it difficult to synthesize and integrate the diverse strands of this literature on agglomeration studies. Therefore in order to sidestep this difficulty only the main concept of industrial districts and clusters shall be examined.

2.1 Industrial districts

The study of concentrations of industry is not new, and indeed it has been the object of attention from a wide variety of perspectives over many years. Corolleur & Courlet (2003; p300) identify they have been observed, since the industrial revolution, in industries such as textiles in Lancashire and cutlery in Sheffield[12]. According to Feser (1998), an industrial district in its simplest form, is a pattern of economic activity whereby smaller firms benefit from co-location. Perhaps a clearer definition is provided by Wilson & Popp (2003; p3) who suggest it is 'a concentration of firms in an industry either in a single town or in a particular area of a larger city'. Marshall (1920) observed these smaller firms benefited from economic side-effects which accrue from concentrating in space and time. This he suggested as taking place within a geographically defined industrial district.

[11] This study follows Brenner's (2004) use of this term.
[12] Alfred Marshall (1842-1924) is considered the first person to observe spatially agglomerations of small firms in Lancashire's cotton and Sheffield's cutlery industries which inspired him to coin the term 'industrial district'. The original discussion of his industrial district concept maybe found in Marshall (1920) Book IV Chapter X

For the first time he revealed how micro-level business relationships might influence regional growth and economic development by him revealing the interdependencies of business structure, business strategy, technology, innovation and the market. He expressed these interdependencies as being 'played out through a nexus that determined the balance of economies of scale and scope available to industry'[13]. Mackinnon & Cumbers (2007) suggested Marshall identified that firms within industrial districts enjoy three main external economies[14]: the pooling of specialised labour, the availability of specialised services, and that knowledge is diffused more rapidly. Marshall (1920) also observed that smaller firms were able to achieve these economies by becoming welded almost automatically into an organic whole – the industrial district. He further saw these as a counterbalance to the economies of scale that larger firms could achieve internally and this in Marshall's mind explained the persistence of concentrations of smaller firms and also their continued prosperity.

Marshall (1920) identified additional economies of scale for firms residing within these districts including the facilitation of large and stable markets in labour skills and equipment. These may also lead to a reduction in costs in subsidiary trades and related business services or promote greater use and development of specialised machinery and organisational methods[15]. One further aspect Marshall (1920) observed was that an 'industrial atmosphere' was present within successful districts, although he wasn't able to completely determine why. He concluded that these industrial atmospheres could not be quickly acquired but yielded benefits to manufacturers that were not easily acquired elsewhere and that they were also static.

[13] Wilson & Popp (2003) p4. Economies of scale meaning here the reduction of the costs of goods with increasing output levels. See Hayter (1997) Chapter 8 pp192-194. Economies of scope are defined as cost reductions associated with a diverse range of products manufactured under one roof or within the same firm. For example, the inter-changeability of parts between 'different' products. However, there are different views as to what 'different' might mean. See Healey & Ilbery (1990) where they also link scope economies with vertical integration.

[14] External or agglomeration economies being benefits or cost reductions outside of the firm itself resulting from the clustering of activities across time and space.

[15] These economies of scale have been observed empirically by Krugman (1991) & Storper & Scott (1992) amongst others. They have been further classified as urbanisation economies, industrialisation economies and localisation economies. See Healey & Ilbery (1990) p88

Despite the age of the industrial district concept, Lazerson & Lorenzoni (1999) and Nachum & Keeble (2003) suggest it still provides a meaningful framework for conceptualizing concentrations of economic, industrial and social activity. This led to some authors, such as Piore & Sabel (1984) and Locke (1995), to herald these industrial district concepts as the central building block of industrial policy for developed market economies. This continued interest in Marshall's ideas stimulated a re-examination in the light of contemporary industries over the last three decades and it is to this newer body of work the next section turns to.

2.1.1 Marshallian Theory: A second reading

A resurgence of Marshall's industrial district concept occurred initially within Italian research in the late 1970s[16]. Subsequently the concept has been relabelled the 'Marshallian industrial district' and 'Italian industrial district' respectably. In the case of the latter it was modified to focus more on the social phenomena occurring within these districts such as clubs, societies and religion[17]. As these new insights were considered there was an increase in the number of approaches to the topic and therefore the Italian industrial district became more diverse. Despite this, some basic characteristics of industrial districts arising from this Italian research were:

- The co-location of a large number of small and specialised firms
- The strong division of labour amongst these firms
- The presence of a social network of the relevant local economic actors favoured by a shared cultural background[18]

[16] This can be traced to Becattini as far back as 1979 who was the first to make the link between Marshall's metallurgical and textile-producing areas of Great Britain and certain concentrations of small firms he observed in new successful regions in Italy.
[17] See Becattini (1990) for an overview of a large part of the early Italian research since the late 1970s. For more recent studies and discussion see: Pyke et al. (1990), Pyke & Sengenberger (1992), Trigilia (1992), Schmitz (1992) and Brenner (2004)
[18] Dijk (1995) as cited in Brenner (2004) p10. A social network defined as inter-firm personal relations which are based on trust and power relations. For a discussion of social networks see Harrison (1992), Amin and Thrift (1992), Gordon and McCann (2000) and Granovetter (2005),

Another influential Italian study was that of Amin & Thrift (1992) of the leather tanning industry in Tuscany where they were able to suggest some of the core features of Marshall's 'industrial atmosphere'. They contended that this area in Italy not only produced the external agglomeration economies typical of a Marshallian industrial district (see section 2.1), but also featured an area-wide asset which individual entrepreneurs could draw upon. In other words, this district, with its many small firms manufacturing medium to high quality leather for shoes and bags, not only produced specialized skills and artisan capabilities (Marshall's local skilled division of labour), but also produced a constant supply of industry-specific information, ideas, inputs, machinery and services. They concluded these complementarities were the main ingredients of Marshall's 'industrial atmosphere' (Amin & Thrift, 1992; p579).

2.1.2 New Industrial Spaces/New Industrial Districts (NIS/D)

Marshall's ideas have stimulated further studies, particularly in the high technology regions of the USA. Subsequently these were seen as different from Italian industrial districts and labelled as 'new industrial spaces' (NIS) or 'new industrial districts' (NID). Here theorization has centred on the importance of vertical disintegration[19] and co-operation among small, flexibly specialized[20] and innovative firms such as the embryonic days of Apple or IBM to the success of the Silicon Valley region.[21] Scott (1992, 1999, 2003 & 2004) has continued to suggest that NIS/D's such as Silicon Valley will become the dominant new paradigmatic form of economic activity in the coming decades.

Importantly, though, Scott's definition of what constituted an NIS/D was virtually the same as that given by Dijk (1995), for Italian industrial districts (see previous page).

[19] Vertical disintegration is defined as the situation in which the production process is broken down between several firms, each performing a limited subset of activities required to create a finished product: see Storper & Christopherson (1987) p260 and Storper & Walker (1989).
[20] The term flexible specialization was introduced by Piore and Sabel (1984) and defined as production which is more craft system based in small and medium sized firms. In industrial districts/clusters it means these firms manufacture a wide range of products by skilled workers using multipurpose machinery; see also Asheim (1992) and Hayter (1997) for discussions on flexible specialization.
[21] This region has received a vast amount of empirical study including, amongst others: Scott (1988a, 1988b, & 1998), Storper & Walker (1989), Langlois (1992) and Saxenian (1991 and 1994).

Namely it comprises (a) geographic concentrations of activities; (b) populations of small and medium-sized firms which are linked together in various ways; and (c) appropriately skilled and accessible labour pools. These then appear to be three re-occurring properties that must exist for an industrial district to be identified regardless of what concept is considered or applied.

2.2 Industrial clusters

The concept of industrial clusters and the clustering of firms has become the principal framework for industrial agglomeration research in the last decade. Throughout this time it has been continually defined by numerous authors in a variety of ways. Table 1 shows how problematic a definition of what a cluster is:

Table 1: Clusters: The confusion of definition

Swann and Prevezer (1996) 'Clusters are here defined as groups of firms within one industry based in one geographical area.' p.139
Enright (1996 & 2003) 'A regional cluster is an industrial cluster in which member firms are in close proximity to each other.' p.191 and p.337
Rosenfeld (1997) 'A cluster... is used to represent concentrations of firms that are able to produce synergy because of their geographical proximity and interdependence, even though their scale of employment may not be pronounced or prominent.' p.4
Porter (1998) 'A cluster is a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities.' p.199
Feser (1998) 'Economic clusters are not just related and supporting industries and institutions, but rather related and supporting institutions that are more competitive by virtue of their relationships.' p.26
Swann and Prevezer (1998) 'A cluster means a large group of firms in related industries at a particular location.' p.1
Roelandt and den Hertog (1999) 'Clusters can be characterised as networks of producers of strongly interdependent firms (including specialised suppliers) linked to each other in a value-adding production chain.' Box. 2 p.414

Simmie and Sennett (1999a & 1999b) & Simme (2001), 'We define an innovative cluster as a large number of interconnected industrial and/or service companies having a high degree of collaboration, typically through a supply chain, and operating under the same market conditions.'p.88; p.51 and p.53.

Crouch and Farrell (2001) '"cluster" suggests something looser: a tendency for firms in similar types of business to locate close together, though without having a particularly important presence in an area.' p.163.

Van den Berg et al. (2001) 'Most definitions share the notion of clusters as localised networks of specialised organisations, whose production processes are closely linked through the exchange of goods, services and/or knowledge. ' p.187

This is why Sayer (1992; p138) and more recently Martin and Sunley (2003) have both argued clusters still to be a 'chaotic conception' meaning it is, despite widespread use, still poorly defined and understood.[22] In side-stepping this impasse Baptista & Swann (1998; p525) prefer a simple, though by no means unproblematic, definition for a cluster as 'a strong collection of related companies located in a small geographical area'. But this still leaves the question: what is a cluster and how is this concept different from the earlier work on industrial districts?

The empirical use of the term cluster as a metaphor also appears problematic. Some authors interchange it with the term district: for example, Martin and Sunley (2003) describe the four district models from Markusen (1996) as cluster models. It would seem therefore the term cluster has become the more fashionable recent metaphor and that perhaps the two theoretical concepts are similar. Perhaps cluster is a better descriptive metaphor as it immediately denotes a concentration of activity whereas district does not. Despite this, more recently some authors feel it necessary to attempt to make a distinction between these terms.

[22] For instance, Swann (2002) noted definitions ranging from 'weak' (simple co-location of firms, technological complementarity, agglomeration with superior performance, and input-output table connections) to 'strong' (Marshallian externalities, labour mobility between firms and explicit inter-firm collaboration).

For example, a cluster (when compared with a district) is seen by Wilson and Popp (2003; p3) as 'a wider agglomeration of industries that may be connected by common products, technologies, markets (either supply or demand) or institutional frameworks'. Thus for these writers the concept of a cluster is not restricted to particular industries or spaces. However, to confuse definition still further there are related concepts of 'regional clusters' and 'industrial clusters' that add those boundaries once again. Despite these problems of definition, the main value of the cluster concept has been to add to Marshall's ideas in revealing a greater number of linkages at play in industrial agglomerations.

Cluster theory, according to Nachum & Keeble (2003; p461), also identifies 'the significance of business networks[23]; the suitability of the labour market; the external supply of intermediate inputs (marketing for example); the interaction with customers and responding to their needs; and the balancing of collaboration and competition with firms and organisations (often NGOs), and also the successful outcomes of collective learning and product innovation'. Marshall was really only concerned with three of these positive outcomes (see section 2.1). Another difference in cluster research is the greater scrutiny of many of these through both formal and informal channels, between firms and entities (trade associations, governmental bodies and NGOs) rather than a focus on the inputs and outputs of firms only and the 'spillovers' or 'secondary effects' caused by those linkages[24].

The concept of clusters has therefore focused upon an understanding the benefits (both traded and untraded) that firms accrue because of their connections with other firms in close proximity to them. Cluster theorists see these profits resulting from co-operation, market relations, spillovers, and in some cases that more local start-up businesses are successful within clustered firms. Over the last 15 years one of the most influential bodies of cluster research has been the work of Michael Porter (1990 & 1998a) in the USA who suggested the clustering of firms promotes competition within that sector and ultimately this increases a country's global competitiveness. The next sub-section now examines Porter's research.

[23] See this chapter page 13 footnote 28 for a definition of network
[24] An overview of these is given in Braunerhjelm & Carlsson (1999).

2.2.1 Clusters and competition

From a business and management perspective Porter's (1990, 1998a & 1998b) use of the cluster concept has been very influential[25]. Overall his work has highlighted the near universal significance of clustering to competitive economic advantage. He introduced what he phrased as a 'diamond' model of forces determining competitiveness, which is very much grounded in Marshallian concepts. In this model he saw clustering activity as producing four important mechanisms which help drive competitiveness: productivity, innovation, flexibility gains and new business creation (also termed spin-offs)[26]. These are very similar to the local self-augmenting processes discussed in the industrial district literature.

Despite the popularity of Porter's cluster theory, for twenty first century policy makers there still remains a major ambiguity in defining what a cluster is. This is Martin and Sunley's (2003; p10) position who suggest the situation in the cluster literature is that we know what they are called, but defining precisely what they are, is more difficult. Porter (1998; p197) defined a cluster as:

> 'Geographic concentrations of interconnected companies, specialised suppliers, services providers, firms in related industries, and associated institutions (for example, universities, standards agencies, and trade associations) in particular fields that compete but also co-operate.'

There appears two core elements to this definition. First, Porter insists, that firms within a cluster must be linked in some way. These links could be vertical (buying and selling relationships) and also horizontal (including complementary products and services, the use of similar specialized inputs, technologies or institutions, and other linkages). Significantly he implies most of these linkages involve social relationships or networks that produce these benefits for the firms involved[27]. He termed this the socio-economy of clusters.

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[25] For a discussion on why Porter's work has attracted considerable interest see Martin & Sunley (2003).
[26] See (Porter, 1998a, 1998b and 2000).
[27] Unfortunately he doesn't define networks at all, but appears to place a great emphasis on them providing the social glue, or in Markusen's words the stickiness, that binds firms together and contributes to the value created in clusters. See Porter (1998a; p225).

More recently Rugman & D'Cruz (2003; p18) have attempted to provide a definition of these networks as webs of relationships that tie the cluster members together. These networks can more precisely be understood by defining what they are not. Linkages within a business network are not simply the transactions between firms in a market or the internal transactions inside the firms themselves: they embody linkages that are achieved through the harmonization of the strategies of the firms themselves. This means they involve elements of both market transactions and intra-firm structures and processes. Resulting from these networking linkages, firms can often make use of resources owned by other firms such as technical or marketing expertise. While some of those external resources are tangible and can be bought, others are intangible such as skills and relationships between people in the firms concerned, for example 'old boys' networks'. This makes these types of networking linkages more difficult to acquire through economic transaction and are very static and difficult to replicate.[28] Considering business networks Porter (1998; p226) suggested that even 'a cluster is a form of network that occurs within geographic location, in which the proximity of firms and institutions ensures certain forms of commonality and increases the frequency and impact of interactions'.

Many problems are raised from this understanding of what constitutes the network of linkages that form a cluster. In these definitions there is a lack of a clear boundary, both industrial and geographical. Also it is difficult to determine at what level of industrial agglomeration a cluster may be identified. Furthermore what range of related industries and activities are internal and how strong do linkages between firms and entities need to be for it to be termed a network? Also how economically specialized does a concentration of firms (in time and space) have to be, for it to be a cluster? The final area of ambiguity is Porter does not appear to insist that clusters are economically specialized entities in the Marshallian sense, yet all his examples are.

[28] A clearer definition of a business network in relation to Porter's work was provided by Casson (2000; p170 and 2003) where he saw them as 'a set of high-trust linkages connecting a set of entities'. He suggests these linkages are based on information flows and that the entities can be either people – forming an *inter-personal network,* or institutional – forming an *inter-institutional network*

He also fails to make it clear at what spatial scale do clustering processes (inter-firm linkages, knowledge spillovers, rivalry, business and social networks[29]) operate. Despite these problems the cluster concept, and in particular the work of Porter, has become widely adopted by regional policy makers who are looking to promote local economic development and researchers looking to understand the continued vitality of regions with concentrations of firms[30]. One way in which Porter's cluster emphasis was applied was in the study of two UK high technology sectors and the next sub-section now discusses this.

2.2.2 Clusters and a life-cycle model

One area of research which has emerged from the cluster and network concepts is that of Swann & Prevezer (1996 & 1998) with regard to the computing and biotechnology industries in Britain. Here they introduced an evolutionary model (the life-cycle model), in which clusters pass through four principal stages: critical mass, take-off, peak entry and saturation, Swann (1998; pp52-54). This model brings into interaction concepts already identified such as agglomeration externalities and positive feedbacks, but adds to this by considering the negative effects that clustering may bring, for example, congestion effects, severe competition and the convergence of technology which emerges as the clustered industry matures.

In analysing both of these new high-tech industries they suggest that firms within clusters grow faster than those in isolation. Clusters also attract a higher rate of entry at least during the early growth phases of the life-cycle for a particular industry. This happens because of agglomeration economies, which impact on entry and growth and lead to a positive feedback and that these effects are strongest when there is geographical concentration. They, like Porter, also highlighted that clustering promotes the easier transmission of tacit knowledge[31].

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[29] Social networks being defined here as inter-firm personal relations heavily based on trust, see Gordon and McCann (2000)

[30] For example a large body of cluster research has emerged on 'Britain's Motorsport Valley' including Henry, Pinch & Russell (1996); Pinch (1997); Pinch & Henry (1999a, 1999b, 2000 & 2001), and Henry et al. (2003)

[31] For a definition see p8.

After a period of growth and prosperity Swann then suggested cluster congestion effects emerge. Rate of entry of new firms and therefore cluster growth begins to slow down or even enters decline. He suggested this happened more so in very large clusters, mainly because the cost of locating in that cluster starts to outweigh the benefits. Added to this he also observed separate technologies, and the industries producing them, beginning to converge. By this he meant there were important cross-sector effects in clusters whereby a growth or decline in industry one affects the same in industry two. If this relationship is strong it is said to be converging, if it has no effect these industries are said to be distinct. Overall Swann's work suggested that clusters were alive and they went through patterns of growth, decline and sometimes renaissance.

Swann's model seems not only to apply to modern high technology industries as Wilson & Singleton (2003) made it central to their work when studying broadly the Manchester industrial district between 1750 and 1939. When applying elements of Swann's (1998) life-cycle model, they revealed a pattern where initially vibrant economic systems emerged through local technical innovations and as these industries evolved, their dynamism, was eroded away or in other words other regions in Britain caught up to Manchester. Therefore in explaining the successful emergence of the Manchester region it was catapulted forward through its central role within the textile and later machine tool industries. Over time gradually other English regions, usually not always in the same sector, began to catch up partly through diffusion of some of those innovations into their related sectors.

The weakness that may lie with the life-cycle model is when applied in this way it demonstrates that each district or cluster is temporally and spatially specific making a generic life-cycle model difficult to formulate.[32] Life-cycle models, then, although revealing much in the recent computing and biotechnology industries only really provide overarching theories that have tendencies to gloss over some of the 'messiness' and complexity of other empirical case studies.

[32] Staber (1996a, 1996b & 1998) is one such critic of such models in stating that no single model can capture the diversity apparent from an empirical study of rich and vibrant industrial regions

Despite this its value has been in bringing to the fore elements of timing (e.g. a cluster has a life of its own) and the existence of negative effects within clusters which had previously been down-played.

2.2.3 The innovative milieu concept (IM)

Another influential concept has been one from France of the 'milieu innovateur' mainly carried out by GREMI[33].
This project investigated French regions outside of large cities and analysed them according to their innovativeness and the local synergies[34] present between firms.
According to GREMI an innovative milieu is defined as:

> The set, or the complex network of mainly informal social relationships on a limited geographical area [therefore they are set within a district/cluster], often determining a specific external 'image' and a specific internal 'representation' and a sense of belonging, which enhance the local innovative capability through synergetic and collective learning processes[35].

To summarize this concept there appears three main sets of features which constituent an innovative milieu:

Table 2: The three main features of an Innovative Milieu (IM)

1. Effective actor relationships within a regional or local cluster This first feature relates to the fact that co-operation and information exchange between key actors of economic development (such as firms, entrepreneurs, and government or non-government organisations) are facilitated by the location of them in the same local district/cluster, and thus in spatial proximity to one another, which allows for easy and frequent face-to-face contacts.

[33] GREMI being an acronym for Groupe de Recherche Européen sur les Milieux Innovateurs. The main results of their original study are summarised in Camagni (1995)
[34] Synergies defined here as outcomes that result from co-operative interaction amongst firms or actors which produce an enhanced combined effect.
[35] Camagni (1991) p3. Emphasis added

For the actual innovativeness to be triggered these actors need to also be the decision makers explicitly coming from different types of organisations (manufacturing or supplier firms, universities, research laboratories, administrative bodies such as committees or trade associations) (Maillat el al. 1993), as creativity stems from the new combination of ideas that belong to different fields of activity that were not associated previously.

These actors can combine complementary capabilities and competencies that are necessary to create new technical solutions or implement new programs. This crucial quality of the innovative milieu to induce and co-ordinate economic change and the regrouping of productive assets have been stressed by GREMI (see Ratti et al. 1997 & Crevoisier 2001). They add that the relevant personal network[36] which develops becomes bound to the locality, but also it needs to be sufficiently open to allow inflows of know-how from outside which enrich the local circulation of information (Le Heron & Harrington 2005).

2. Social contacts that enhance learning processes

A second main feature of the innovative milieu relates to specific advantages of embedded learning processes. Exchanges of know-how and acceptance of other people's advice are favoured by good informal, often also private contacts, between individuals with a high degree of mutual trust, for example, 'old boys' networks'. These face-to-face contacts allow fast flows of confidential or non-routine information as uncertainty is reduced and learning and therefore innovation accelerated (Sweeney 1987). This effective combination of personal, professional and private relationships not only provides preferential or cost-free access to strategically important news or services, but also acts as a form of emotional support which reinforces business decisions to innovate through providing motivation, encouragement and recognition (Fromhold-Eisenbith 2002).

3. An image or sense of belonging

The final feature of the innovative milieu suggests that actors are aware of forming a coherent unity or collective image, which can be demonstrated to those external to

[36] See this chapter page 13 for a definition of network

the locality. A sense of belonging also determines the spatial extent of the innovative milieu where the limit is seen as where social coherence fades out (Maillat el al. 1993). This fulfils an important function by harmonising the individuals' differing professional backgrounds and interests and directs them towards common goals.

A final point to note is that all three milieu features are often activated by upcoming crisis that call for the need to join forces. Military conflict or market forces being two such examples.

Sources: For a summary of the I.M. concept see Fromhold-Eisenbith (2002) & Le Heron & Harrington (2005)

The value of this concept has been to stress the importance of informal and untraded linkages between firms and the importance of social aspects to firms' behaviour, innovativeness and to a regions economic growth and prosperity.

2.2.4 Summary of the cluster concept

Despite the problems of defining what constitutes an industrial district or cluster, it is still seen a useful concept for the studying of geographical concentrations of firms. Henry & Pinch (2006) suggest the 'added value' in the cluster concept is to shift an understanding by moving analysis away from overt, traded, exchanges of commodities and services towards the study of predominantly untraded exchanges of knowledge and ideas. This has resulted according to Lovering (1999) and Martin & Sunley (2003) in a body of cluster research, with Porter at the centre, to be widely regarded by many national governments and local and regional development professionals as a universal panacea for encouraging economic competitiveness at all scales.

Having now discussed both the problems, and insights that the literature on districts and clusters have brought to the study of concentrations of firms the third and final section now wishes to suggest how all of this can be brought together to form a meaningful conceptual framework for the study of Coventry's First World War armaments and munitions industry.

2.3 Towards a classification of Industrial Districts/Clusters

Further empirical studies have tried to differentiate types of industrial clusters rather than continually searching for a singular idealised form[37]. Again an impetus to classify industrial concentrations comes from Italian research with a recent government programme setup to identify different types and the locations of industrial districts[38]. The weaknesses of this classification are the social phenomena becomes side-lined or neglected, mainly because they are difficult to measure, and secondly larger firms are often ignored altogether.

In light of these problems Markusen (1996 & 2003) has been able to put forward a four district typology from US research, each with distinctive industrial structures and relationships to external organizations and markets. Another more recent formulation is provided by Gordon and McCann (2000 and 2005) who use the term industrial clusters. Markusen's earlier typology considers the way to differentiate different industrial district types is to examine their spatial element and the relationships between the firms and entities both internal and external to the district. In contrast, Gordon and McCann determine a three cluster typology by examining the complex processes that may underlay such concentrations of firms. As this study wishes to examine the spatial dimension of Coventry's First World War armaments and munitions cluster it is Markusen's earlier industrial district classifications which are now discussed.

2.3.1 Markusen's industrial district typology

A first industrial district observed by Markusen (1996) is the same type already discussed which was identified in the Emilio-Romagna region of Italy or Silicon Valley in the USA and termed as Italian Industrial Districts or New Industrial Spaces/Districts[39].

[37] According to Paniccia (1998; p667) this desire stems from the fact that behind the academic use of the term, many different forms of organization of labour and different socio-cultural contexts are hidden.
[38] Tappi (2003) gives an overview and discussion of these developments.
[39] See this chapter section 2.1.1 and 2.1.2. In addition for an comprehensive study of the 'Third Italy' see Piore & Sabel (1984) and Sabel (1989) and for a discussion on NIDs see Storper (1989) and Scott (1988a and 1999).

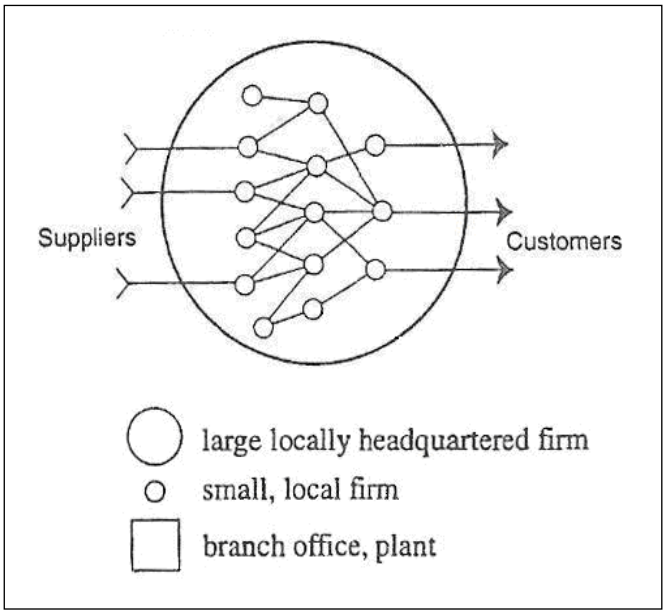
Added to this Markusen also identifies three more industrial districts which she terms as 'sticky places'. In other words, geographic space which acts like sellotape, and has the ability to attract, retain and nurture economic activity. The definition she gave was 'an industrial district is a sizeable and spatially delimited area of trade-orientated economic activity which has a distinctive economic specialization, be it resource-related, manufacturing, or services'[40]. The following sub-sections now summarize each of the four industrial district models she identified[41].

2.3.1a A Marshallian/Italianate/New Industrial Space/District (NIS/D) Model

This refers principally to the industrial district outlined earlier. However, by building on Marshall's observations Markusen (1996) also noted that firms in this type of district make investment and production decisions locally. Trade within this district is transacted between buyers and sellers which often entail long-term contracts or commitments. Something Marshall did not observe, but identified by Markusen, is that linkages and/or co-operation with firms outside the district tend to be minimal. Figure 1 depicts how she saw this form of industrial district in operation:

[40] Park & Markusen (1994) and Markusen (1996) p296.
[41] See Markusen (1996) pp298-299 Table 1 for a detailed list of the hypothesized features of each of the four distinct district types.

Figure 1: A Marshallian/Italianate/(NIS/D) Industrial District



Source: Adapted from Markusen (1996) p.297 Figure 1

This district type is therefore comprised of many small firms buying and selling from each other for eventual export from the region. The left-hand arrows depict the necessary purchases of raw materials and business services from outside the region and the products eventual sale to external markets on the right-hand side. This is in a form of exchange rather than any form of co-operative relationships external to the region. The many small firms within the region benefit from the quality and nature of the local labour market which is highly flexible. Individuals move from firm to firm, and owners as well as workers live in the same community, where they benefit from the fact that 'the secrets of industry are in the air'. Workers are committed to the locality more so than the firm. Labour out-migration is minimal and growth in the region stimulates in-migration. This form of district is seen as a relatively stable community of firms, resulting in a strong local cultural identity and shared industrial expertise. This is through tacit knowledge exchange.[42] Effective transfer of this knowledge generally requires extensive personal contact and trust.

Specialized service industries also emerge inside these districts and are often tailored to unique products or industries located there.

[42] Knowledge that people carry in their mind which means it is difficult to access and codify.

These services may include technical expertise in certain product lines, machinery, marketing or repair and maintenance services. They may also include local financial institutions offering so called 'venture capital'. These often take longer-term risks because they have both inside information and greater trust in the entrepreneurs of local firms Markusen (1996; pp299-300). All of these features are captured under the umbrella term of external agglomeration economies (see section 2.1). It is these which according to Markusen (1996) produce the stickiness of a place, not the individual firms themselves nor their entrepreneurs and workforce. A final consideration unobserved by Marshall (1920) is actors within this district at all times are consciously (and perhaps sub-consciously) co-operating and competing with each other in order for the district to exist, expand and prosper.

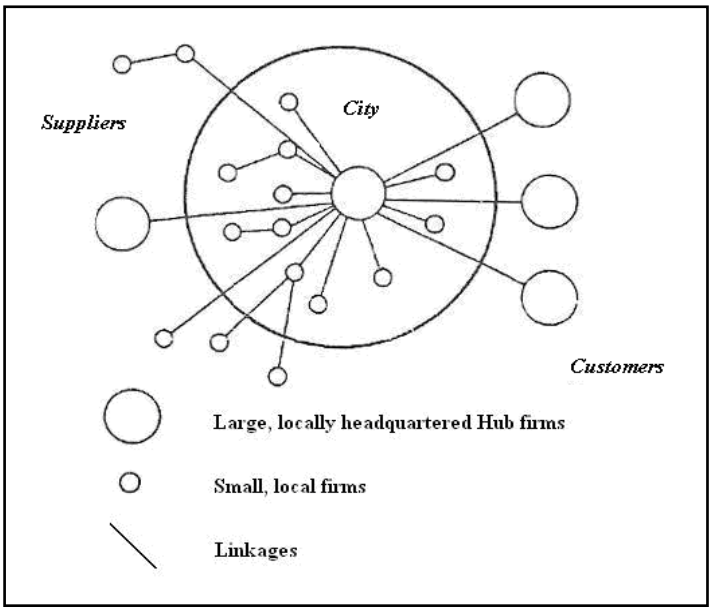
Having outlined Markusen's (1996) first idealised district her second is now summarized.

2.3.1b A hub-and-spoke industrial district

This district is where a number of key firms and/or facilities act as 'hubs' to the regional economy. From these 'hub' firms, suppliers and related activities spread out like the spokes of a wheel[43]. The following Figure 2 is a simplified depiction of a hub-and-spoke district in operation:

[43] Examples of this type of industrial district have been identified in Seattle, USA by Gray et al. (1996) where Boeing, Microsoft and two education/research establishments all acted as 'hubs' in that economy. Likewise 'Toyota City' in Japan has been another hub-and-spoke-district put forward by Gordon and McCann (2000) and lastly Nachum & Keeble (2003) have demonstrated it empirically for media firms in London, England.

Figure 2: A hub-and-spoke industrial district



Source: Adapted from Markusen (1996) p.297 Figure 1

Here the large 'hub' firm buys from both local and external suppliers and sells mainly to external customers. Crucially the dynamism in this district is associated with the positionality of the 'hub' or anchor firms and organizations in their national and international markets. Hub-and-spoke districts are thus dominated by one or several large, vertically integrated firms, in one or more sectors. They are then surrounded by smaller and less powerful suppliers. There is also some internal variety as they may exhibit a strongly linked form. Here these smaller firms are very dependent on the large 'hub' firms and institutions or even infrastructure 'hubs' such as ports and airports for markets or supplies.

Another pattern may take a weaker, more nucleated form, where small firms in the district enjoy the external agglomeration benefits of the 'hubs' without necessarily buying or selling to them. Furthermore in some of these districts the 'hubs' act as oligopolists[44].

[44] This is where there are only a few firms in the industry and they can greatly influence price and stabilise market conditions sometimes through collusion. Also usually a business decision in one oligopoly firm affects another.

Examples include the automotive industry with the big three automotive corporations (Ford, Chrysler and General Motors) in Detroit, USA or the Toyota company in 'Toyota City', Japan which both dominated their industrial districts and markets. Markusen (1996) suggests key investment decisions for these 'hubs' are made locally, but their effects are felt globally. There may also be present intra-district co-operation (between firms in the same district), but she also suggests this will generally be on the terms of the 'hub' firm. The intra-district trade which does occur tends, like a Marshallian/Italianate/(NIS/D) district, to take the form of long-term contracts and commitments. However, exchanges of personnel take place to a lesser extent than the Marshallian/Italianate/(NIS/D) industrial district.

Additionally what is markedly lacking in a hub-and-spoke district is the co-operation between competitor firms to share risk, form a stable market, and to share innovations. Any strategic alliances that are formed are likely to be forged with partners outside the region. There are also differences in the labour market as here it is less flexible than in the Marshallian/Italianate/(NIS/D) model. This is because workers loyalties are to the 'hub' firm, then to the district and lastly to the smaller less 'spoke' firms. If jobs became available in the 'hub' firm, workers will often 'jump ship' to obtain them. This of course makes it tough for small firms in these districts to survive, but a counterbalance to this is the 'hub' firms often attract new labour into the district through in-migration.

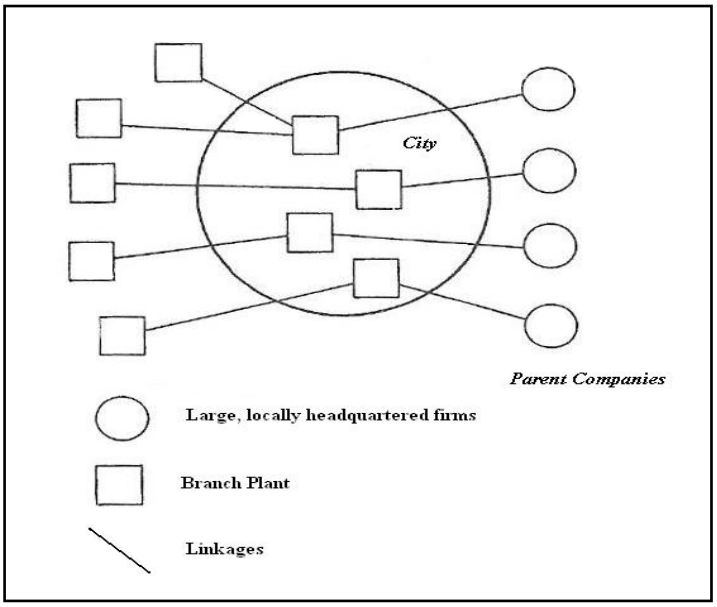
Fresh capital within hub-and-spoke districts is often a lacking for local start-up firms. The largest sums tend to be tied up as retained earnings in the major 'hub' firms who do not reinvest them locally, but redeploy them wherever their global or national strategic plans demand. Trade associations (when present) are weaker than in the case of the Marshallian/Italianate/(NIS/D) usually because 'hub' firms have the power, if so desired, to alienate themselves from their activities. According to Markusen (1996) hub-and-spoke districts are highly dependent on their 'hub' firms for their stickiness. If these 'hub' firms or industries enter an economic downturn the whole district suffers and this is an inherent weakness of this form of economic concentration.

Having now outlined Markusen's (1996) second industrial district the third is now summarized.

2.3.1c A satellite platform industrial district

This district differs as it is chiefly composed of branch plants of externally orientated multinational corporations. This type of district may either consist of high-tech branch plants or chiefly contain low-wage, low-tax, publicly subsidized establishments. These can sometimes be also assembled at a distance from major conurbations by national governments. They can also be set up by entrepreneurs as a way of starting regional development by escaping the high wages and rents in successful districts or cities, for example, some of the science parks established in England since the 1990s. Tenants of satellite platforms may range from routine assembly plants to relatively sophisticated research firms, but Markusen (1996) suggested they must 'stand alone'.[45]

Figure 3: A satellite platform industrial district



Source: Adapted from Markusen (1996) p.297 Figure 1

[45] Glasmeier (1988) explained this as these firms must be detached spatially from either up or downstream operations within the same firm or from agglomerations of competitors and external suppliers or customers.

Satellite platforms have been identified in almost all countries regardless of developmental stage.[46] Concerning the structure within these satellite platforms they are dominated by large externally headquartered firms that make key business decisions outside the region. Scale economies[47] within these branch plants are moderate to high and turnover is usually moderate to low. Importantly, there appeared to be minimal intra-district trade or communication between these so called platform tenants. Contracts, both formal and informal, are lacking from local suppliers and these branch plants are very externally orientated. As these firms are remotely controlled they do not easily form joint ventures to share risk, stabilize the market, or engage in innovative partnerships[48]. In this respect they diverge from a hub-and-spoke model where the larger firm is locally based. Therefore this district's most important feature, (as shown in Figure 3), is the complete absence of any form of connections, networks or linkages within the region[49]. There is only the predominance of linkages outside the region with other branch plants or to the firms' headquarters.

It would be a mistake to describe these branch plants as isolated as they are embedded into a network of external relations. They cooperate and communicate daily with their parent companies and also personnel exchanges occur along these same channels. To reinforce this non-place embeddedness high-tier managerial and technical staff in an early developed satellite platforms cut across district boundaries. In other words they are internal to these vertically integrated firms, rather than the district itself. This can become applicable to all labour once the satellite platform becomes well established. This results in high labour migration in and out of these districts, especially for managerial, professional and technical staffs. The availability of capital within these districts is also operated through external channels.

[46] Examples include Kumi in South Korea with low-end textile and electronics firms. Diniz and Borges Santos (1995) highlighted an area of Manaus in Brazil where state sponsored expansion has developed an import/export zone. Markusen and Sasaki (1994), amongst others, have termed these platforms as 'technopoles', such as those also located at Oita and Kumamoto in Japan

[47] See section 2.1 for definition

[48] This is because key decision makers, who would usually take a lead in these activities, are not present within the district.

[49] Network defined as a series of tangible and intangible linkages which help to bind firms, entrepreneurs and infrastructure together within the district.

Technical expertise and business services may also be external to the region and furnished through a firm's headquarters. Satellite platform districts, according to Markusen (1996), therefore have little local capital to draw upon. Moreover, because the activities of these branch plants can be diverse there is a weak pressure to form trade associations. Long term growth in these districts is possible, but it is constantly threatened by the portability of these branch plants to another region. This vulnerability can be further explained as these plants are very much outward looking and therefore do not engender strong cultural bonds locally. They also do not establish a new identity for a region even though by their presence they may destroy existing ones.

Thus their main weakness, when compared to the Marshallian/Italianate/(NIS/D) and the hub-and-spoke districts, is that they are less sticky. However, they can generate some stickiness by the large capital investments which are implemented when these branch plants are first established: for example, through infrastructural upgrading such as new road, rail, air or port facilities.

Having outlined Markusen's (1996) third industrial district the last one is now summarized

2.3.1d A state-anchored/centred industrial district

This district type has been identified through studies into the rise of military establishments throughout the USA during the cold and first Gulf Wars[50]. It is a more eclectic district where a public or non-profit entity: for example, a military base, defence plant, weapons laboratory, university, prison complex, or a concentration of government offices are the key anchor tenant within the district. Here the local business structure is dominated by the presence of these facilities which are often located into a region through political or defence considerations rather than by market forces. According to Markusen (1996) it is more difficult to theorise and this is why she could not represent it diagrammatically and why one is not reproduced here.

[50] For these see Markusen (1991) and Markusen et al.(1991)

Despite this, she suggested it would look similar to that already given for a hub-and-spoke district (figure 2) in so much as it could involve larger embedded 'hubs' within this district, but it would have fewer linkages to the regional economy and therefore is this respect it is similar to the satellite platform model (figure 3).Despite these similarities there are some unique features that can be noted which make this the fourth type of industrial district. Perhaps the best way to illustrate their existence is through examples. Military bases, academies and weapons labs, largely explain the post-war growth of U.S. cities such as Santa Fe, Albuquerque, San Diego and Colorado Springs. Added to this Markusen (1991) and Gray (1996) identified it was through a series of defence plants that contributed to the early growth of Los Angeles, Silicon Valley and Seattle.

In terms of non-military anchors, Markusen (1996; p306) highlights Denver owing much of its post-war growth due to it hosting the second largest concentration of federal government offices within the USA. Additionally Diniz and Razavi (1994) identified in Japan and South Korea it was government research complexes at Tsukuba and Taejon that fuelled economic and urban growth there. They further noted in Brazil, the city of Campinas owed much to its top-ranked university, while San Jose dos Campos's growth is based around a government-owned, military-orientated aerospace complex.

In general, scale economies[51] in these complexes are relatively high. This is because state-owned or state-orientated facilities are so large, supplier sectors do grow up around them and they become dependent on public expenditure. Short-term contracts and commitments exist between these anchors and their surrounding local suppliers, but this can be subject to political change. Long-term contracts can emerge in areas where the anchor is a defence establishment. This is because they are based largely on trust and cooperation and the procurement process is usually protracted in these instances and this means buyer-supplier relationships can extend over longer distances.[52]

[51] See section 2.1 for definition

[52] For example, between Silicon Valley and Washington D.C. in the U.S.A, or along the entire length of Britain between shipyards at Govan and Portsmouth, when constructing sections of warships for the Royal Navy.

Markusen (1996) also suggested labour markets within these districts were tailored to the particular state activity hosted where the workers loyalties will be to the large state institutions and/or state-dependant facilities first, then to the district and then to the firms themselves. Local firms will play a less significant role in these districts than in the Marshallian/Italianate/(NIS/D) or hub-and-spoke districts and will not be in a position to stabilize the market from cooperation or by sharing risks. As in the satellite platform model, trade associations are suggested to be weak, but local government also within this district. Local fixed capital may therefore come from central government in the form of boosterism to enhance the anchor facility. However, there is little consideration to regional investment in these districts.

Long-term growth in state-anchored districts depends on two factors: first, the prospects of the facility at the centre of the region, and second, the extent to which they can generate spin-offs[53]. These can be new businesses or increasing the labour supply in the region and are termed as 'secondary effects'. The problem with developing these is that often the anchor within the district is so large it overwhelms any contribution that could potentially be made by any spin-offs or 'secondary effects' to local regional development.[54] Due to the high dependence of these districts on these single key anchors local business and political energy is always centred on solidifying their commitment to the district and at the expense of other local firms.

Having now outlined the four industrial district models identified by Markusen (1996) it is timely to summarise their usefulness and limitations as a conceptual framework for this study.

[53] Spin-offs are new firms or facilities formed by a split from a larger one. An example could be a new company forming from a university research group. However, in state-anchored/centred districts the main ones tend to be government spin-offs.

[54] Examples of hugely dominant anchors include the Los Alamos research facility in New Mexico, USA with an annual budget of $1.4 billion, Markusen (1996; p307). In the UK the large 169-acre BAE systems submarine facility at Barrow in Furness, Cumbria where c.3,200 steelworkers, designers, engineers, fitters, electricians and other skilled workers are all dependent upon this key anchor firm. BBC NEWS *'New nuclear sub is lifeline for Barrow'* by Toby Poston, Monday, 28 August 2006, see bibliography for web-address.

2.3.2. Summary of Markusen's industrial districts

Markusen's typology provides a useful framework for revealing the diversity of industrial districts. However, even she points out that they are suggestive rather than being definitive Markusen (1996; p308). Further empirical research is still needed to validate the different types she outlined and also to reveal their applicability to other historical concentrations of industrial activity. Also if and how a district can change from one type to another seems another possible question that this study could address.

To blur the boundaries between Markusen's four district typology some regions show elements of all four types. To use the region which has received considerable research, Silicon Valley in California, there Saxenian (1994) suggested the electronics industry confirmed to a Marshallian model, but also revolved around several 'hubs' such as Lockheed, Hewlett Packard and Stanford University. At the same time it hosted a platform of several large branch plants of U.S. and non-U.S. firms including IBM, Oki, NTK Ceramics, Hyundai and Samsung. Finally it had also been one of the largest recipients of military spending in the U.S.A. suggesting it has properties of a state-anchored/centred district.

Overall the weakness of Markusen's industrial district typology appears it focuses too much on 'big business' including the large multinational firms and their role and linkages to central government[55]. This means it does not capture the full diversity of a region. It has been left mainly to Italian research[56] to incorporate SMEs and to establish their role within these districts. This district typology also seems to concentrate too often on observable linkages between firms, for example, formulised contracts. This means it cannot fully identify and explain what Marshall's 'industrial atmosphere' actually is. In order to tackle some of these issues a related concept, that of the innovative milieu, has emerged and it to this that the next section now discusses.

[55] However, perhaps a focus on 'big business' is to be expected from US research.
[56] See Becanttini 1989, 1990, 1991 2003 2004; Brusco 1986 1989 1990 1992; Lazerson & Lorenzoni 1999 and Paniccia 1998, 2002)

2.4 The conceptual framework for this study

From an examination and discussion of the wider literature on industrial districts and clusters this study is now better informed as to where to position an investigation of Coventry's First World War armaments and munitions industry. This study shall base its conceptual framework around three key elements from the literature:

1. To add to the work on industrial districts by relating Markusen's (1996) four idealised models to a British wartime armaments and munitions industry.
2. To synthesize these models with the newer work on clusters involving a greater scrutiny of both tangible and intangible linkages between firms of all sizes and other entities such as trade associations in order to understand how and why this First World War industry was successful.
3. Lastly to incorporate some of the work on networks, including the innovative milieu concept, to identify if social aspects were also important to Coventry firms.

Drawing together these related concepts this study now has a diverse and yet meaningful conceptual framework to relate an investigation of Coventry's WWI armaments and munitions industry with. Before this is undertaken one final area to clarify is to outline a clear conceptual boundary.

As has been suggested the concepts of industrial districts and clusters are similar and the terms interchangeable within the literature. For this study, Brenner's (2004) term: local industrial cluster (LIC), seems to provide an appropriate conceptual boundary for this study. The use of this term denotes the spatial scale as that of a city (Coventry) and not that of a region (the West Midlands). That the study is firm/industry centred.[57] Finally the adoption of the newer metaphor cluster denotes it is not based upon a singular industry. In this case it is based on a set of interconnected light engineering industries.

[57] Therefore banks, shops, trade unions and other service sectors are not widely considered

Furthermore cluster also suggests the study shall scrutinise a variety of linkages and/or networks which may be present.

Having now placed this study into the wider context of existing research themes linked to industrial districts and clusters the next chapter now wishes to outline an appropriate research methodology for this study.

Chapter 3: Research Methods

Having outlined how an evolving agglomeration of industry may be theorised using a cluster approach, the methods through which this may be researched are now discussed. Whilst cluster theory can support a range of methodological techniques, it does require the use of both extensive, quantitative research to identify patterns and more intensive, qualitative research to explain those patterns. For this reason the research methodology was divided into an extensive and intensive phase. This section shall begin by outlining the justification for these two phases. It will then detail how both the extensive and intensive phases were conducted and which methodologies were utilised.

3.1 Extensive and Intensive Research

Sayer (2000) argues that concrete research relies on having complementary extensive and intensive methods. Philip (1998) suggested that in social science research a quantitative, extensive method usually takes the form of structured interviews, questionnaires, experiments, structured observation, content analysis and the analysis of official statistics[58]. Some of these extensive methods are necessary in this research to ask the more general questions of Coventry's Local Industrial Cluster (L.I.C.). They will be quantitative in nature and are concerned with revealing the broad properties and patterns over the entire cluster. However, in using extensive research methods, such as content analysis, explanatory power is arguably sacrificed so that representativeness may be achieved[59]. In other words the extensive phase will be useful in showing how widespread Coventry's WWI armaments and munitions cluster was, but it shall be weak in terms of explaining the cluster and identifying the reasons for its development. This problem is addressed by having a more intensive, qualitative second phase.

An intensive phase of this research is therefore required to reveal an understanding of how particular companies and entities were operating within the cluster.

[58] Philip (1998) p264
[59] Cloke, Philo & Sadler (1991) p156.

In so doing it helps to reveal any casual processes and mechanisms behind specific events, for example the setting up of the Ministry of Munitions in May 1915 could potentially be one event which instigated processes within the cluster. However, as Sayer (1997; p118) notes 'discovering how a mechanism works does not tell us how widespread that mechanism is' and this is why the extensive earlier phase is required to address this. The following table 3, adapted from Sayer (1984), is now given which summarises the research strategy adopted and shows how both phases help to answer different sorts of complementary questions concerning the historical geography of the armaments and munitions cluster under investigation:

Table 3: A Summary of Extensive and Intensive Research

	Extensive	**Intensive**
Research Question	What are the regularities, broad patterns and distinguishing features of a population of armament and munition firms forming a cluster? How widely are certain characteristics or processes distributed or presented within the L.I.C.?	How does a particular firm, entrepreneur or sector work in a particular case or small number of cases? What produces a certain change within the L.I.C.? How did the agents such as committees or individuals operate?
Relations	Formal relations of similarity	Substantial relations of connection
Type of groups studied	Taxonomic groups	Causal groups
Type of account produced	Descriptive 'representative' generalizations, lacking in explanatory penetration	Causal explanation of the production of certain cluster changes or events, though not necessarily representative ones to the whole cluster or for other clusters
Typical methods	Large-scale survey of all engineering businesses and support entities to form a representative sample using content analysis	Study of individual companies, agents and individuals in their casual contexts using qualitative analysis of emergent themes

Limitations	Although representative of a whole cluster of factories and actors in Coventry between 1914 and 1918 it is unlikely to be generalizable to other industrial clusters at different times and places. Limited explanatory power.	Actual historical occurrences and contingent relations between firms and other entities are unlikely to be 'representative', 'average' or generalizable.

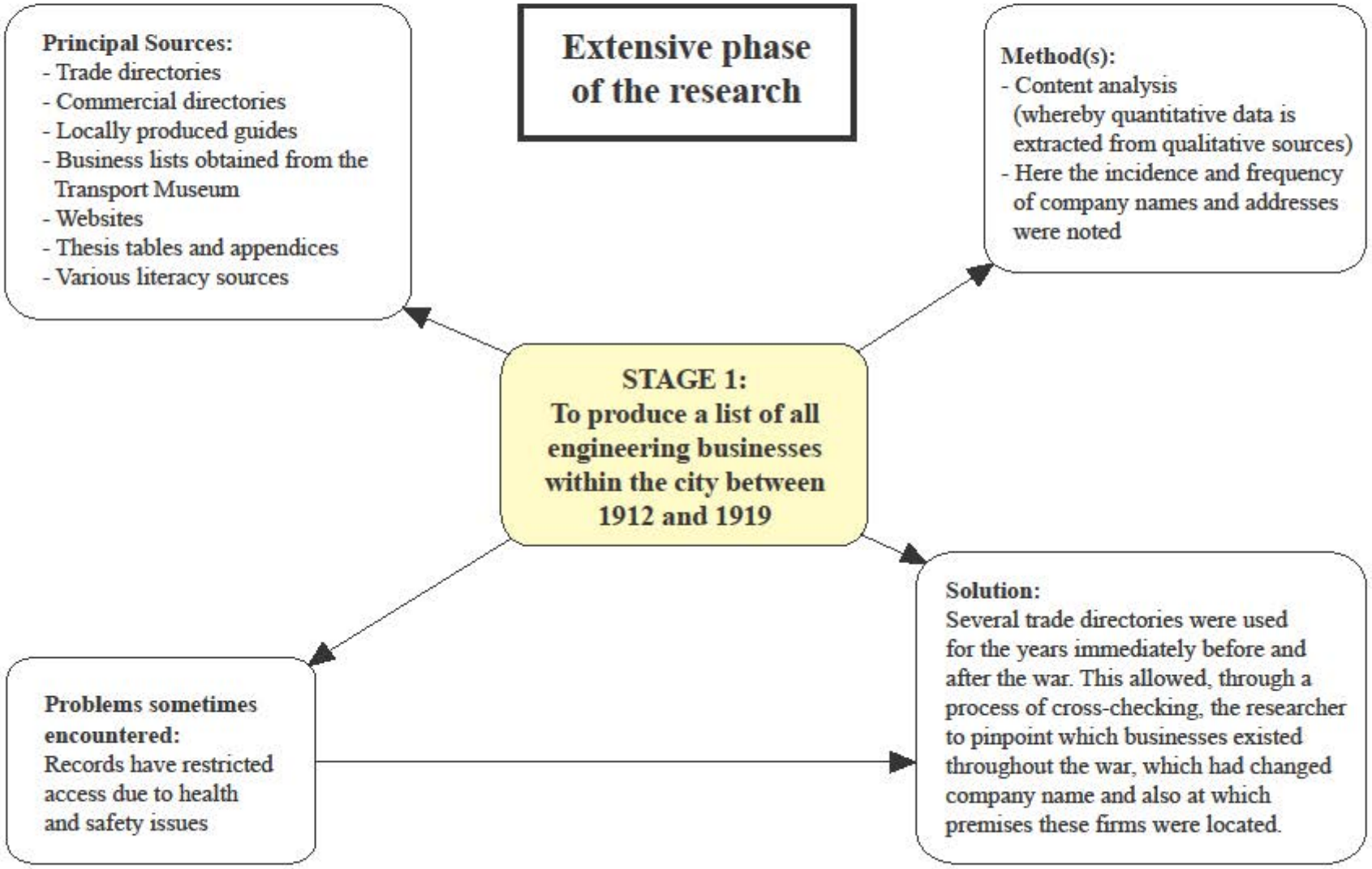
Source: Adapted from Sayer (1984) cited in Cloke, Philo & Sadler (1991) p155.

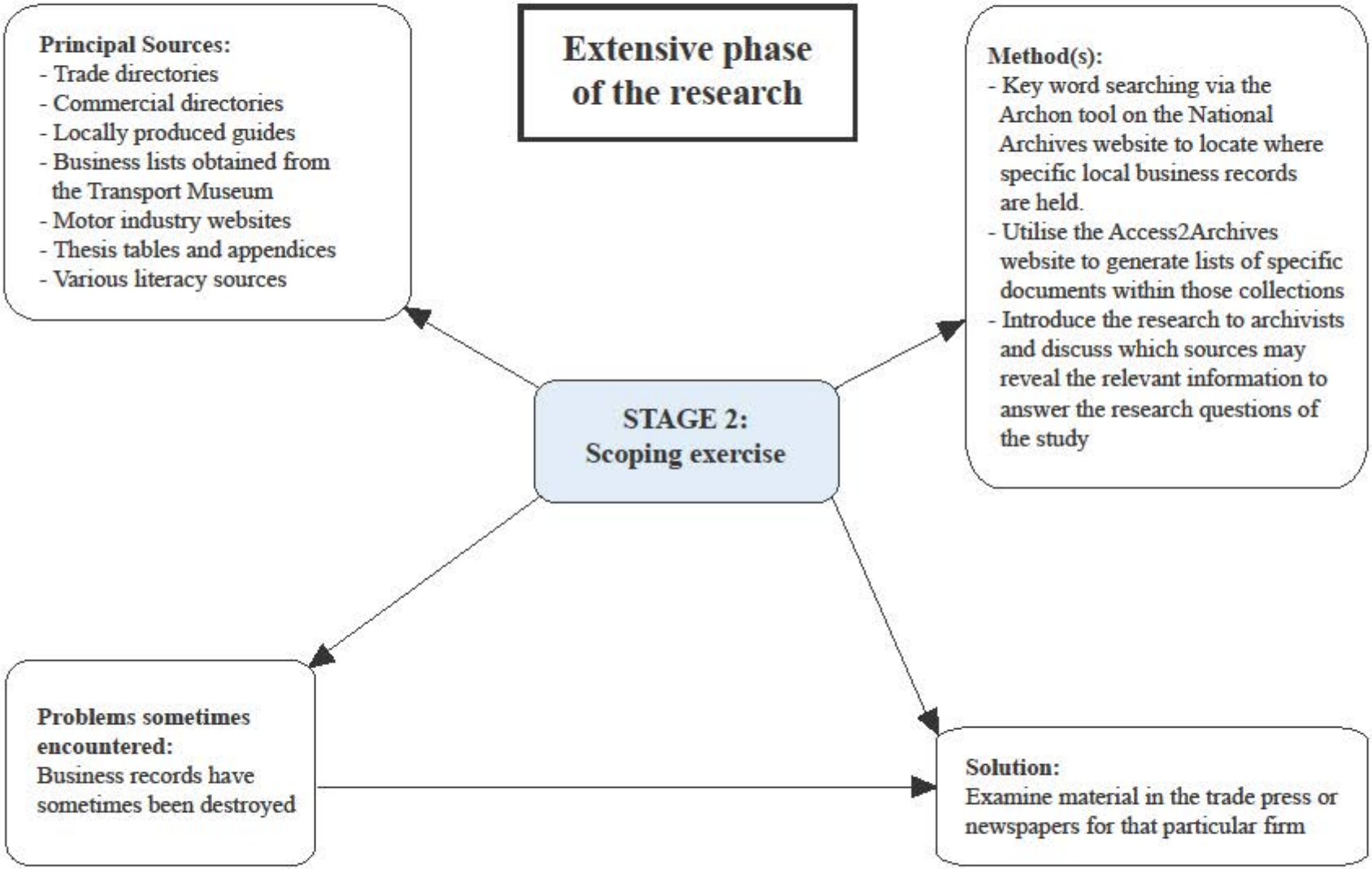
3.2 Extensive Research Phase

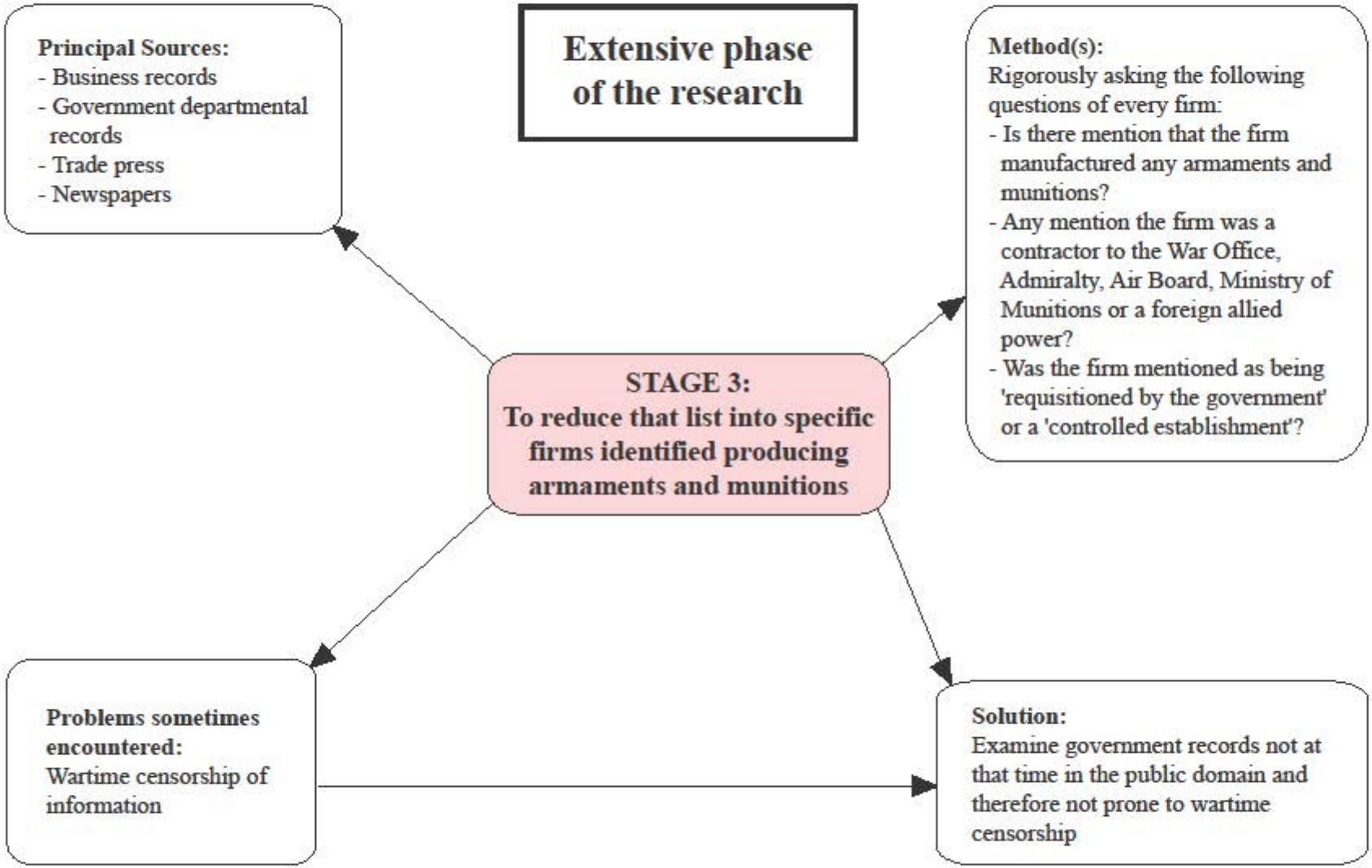
The purpose of this phase was to meet objectives one and two of the research which were to identify and map the armaments and munitions cluster. This phase is necessary to identify broad patterns, regularities and the overall distribution of this cluster. There were four stages to this extensive phase: first to produce a list of all engineering businesses within the city between 1912 and 1919; second to conduct a scoping exercise to investigate what archival material existed for firms; third to then reduce that list into specific firms identified producing armaments and munitions; and fourth to map those firms over three time periods of the First World War.

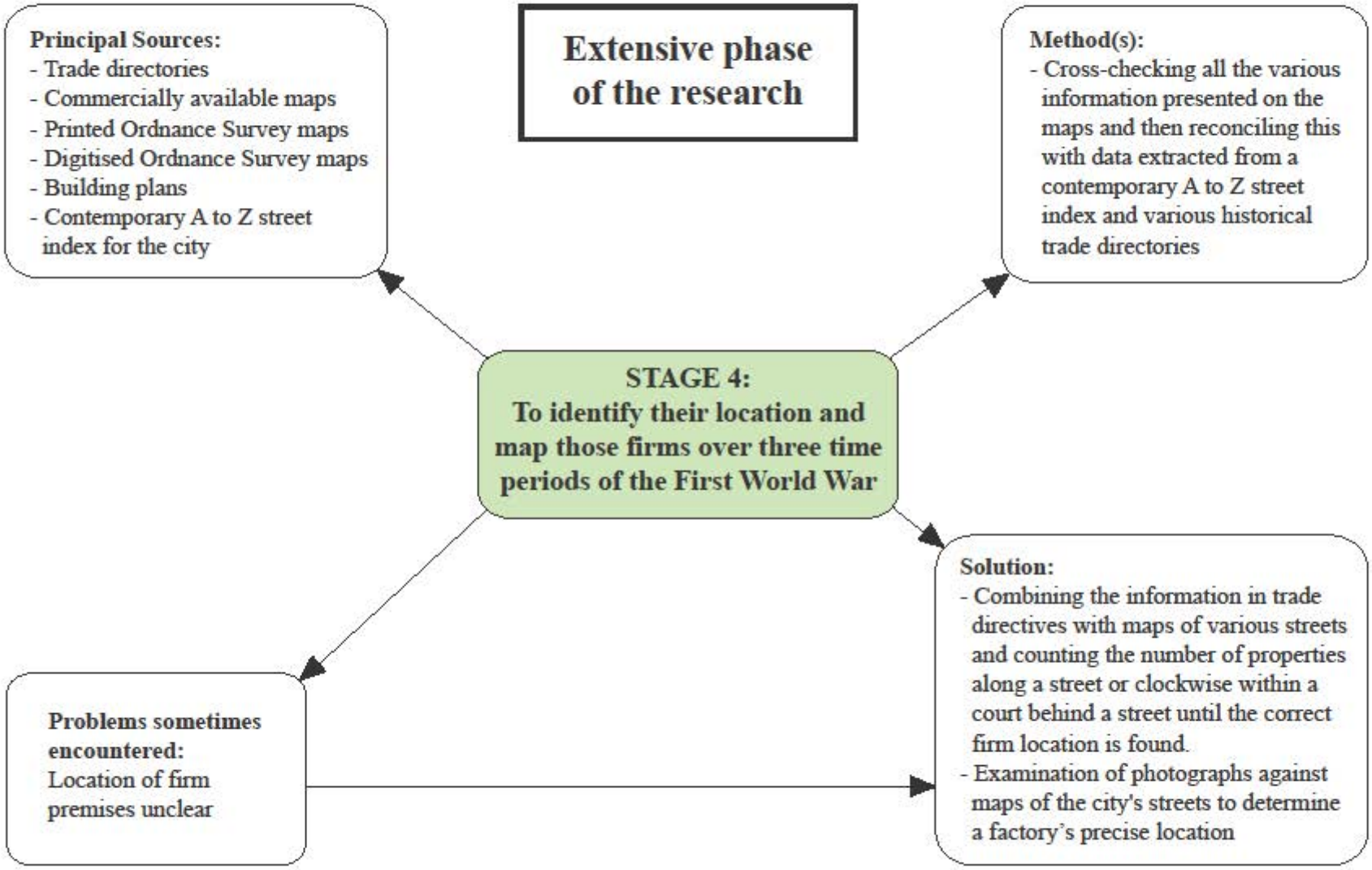
The following four diagrams (overleaf) all summarize each of these four stages to the extensive phase and outline some of the principal sources, method(s), problems encountered and the solutions implemented:

Figure 4: Producing a list of Coventry engineering businesses between 1912 and 1919




Extensive phase of the research
Principal Sources:
- Trade directories
- Commercial directories
- Locally produced guides
- Business lists obtained from the Transport Museum
- Motor industry websites
- Thesis tables and appendices
- Various literacy sources
Method(s):
- Key word searching via the Archon tool on the National Archives website to locate where specific local business records are held.
- Utilise the Access2Archives website to generate lists of specific documents within those collections
- Introduce the research to archivists and discuss which sources may reveal the relevant information to answer the research questions of the study
STAGE 2:
Scoping exercise
Problems sometimes encountered:
Business records have sometimes been destroyed
Solution:
Examine material in the trade press or newspapers for that particular firm


Extensive phase of the research
Principal Sources:
- Business records
- Government departmental records
- Trade press
- Newspapers
Method(s):
Rigorously asking the following questions of every firm:
- Is there mention that the firm manufactured any armaments and munitions?
- Any mention the firm was a contractor to the War Office, Admiralty, Air Board, Ministry of Munitions or a foreign allied power?
- Was the firm mentioned as being 'requisitioned by the government' or a 'controlled establishment'?
STAGE 3:
To reduce that list into specific firms identified producing armaments and munitions
Problems sometimes encountered:
Wartime censorship of information
Solution:
Examine government records not at that time in the public domain and therefore not prone to wartime censorship

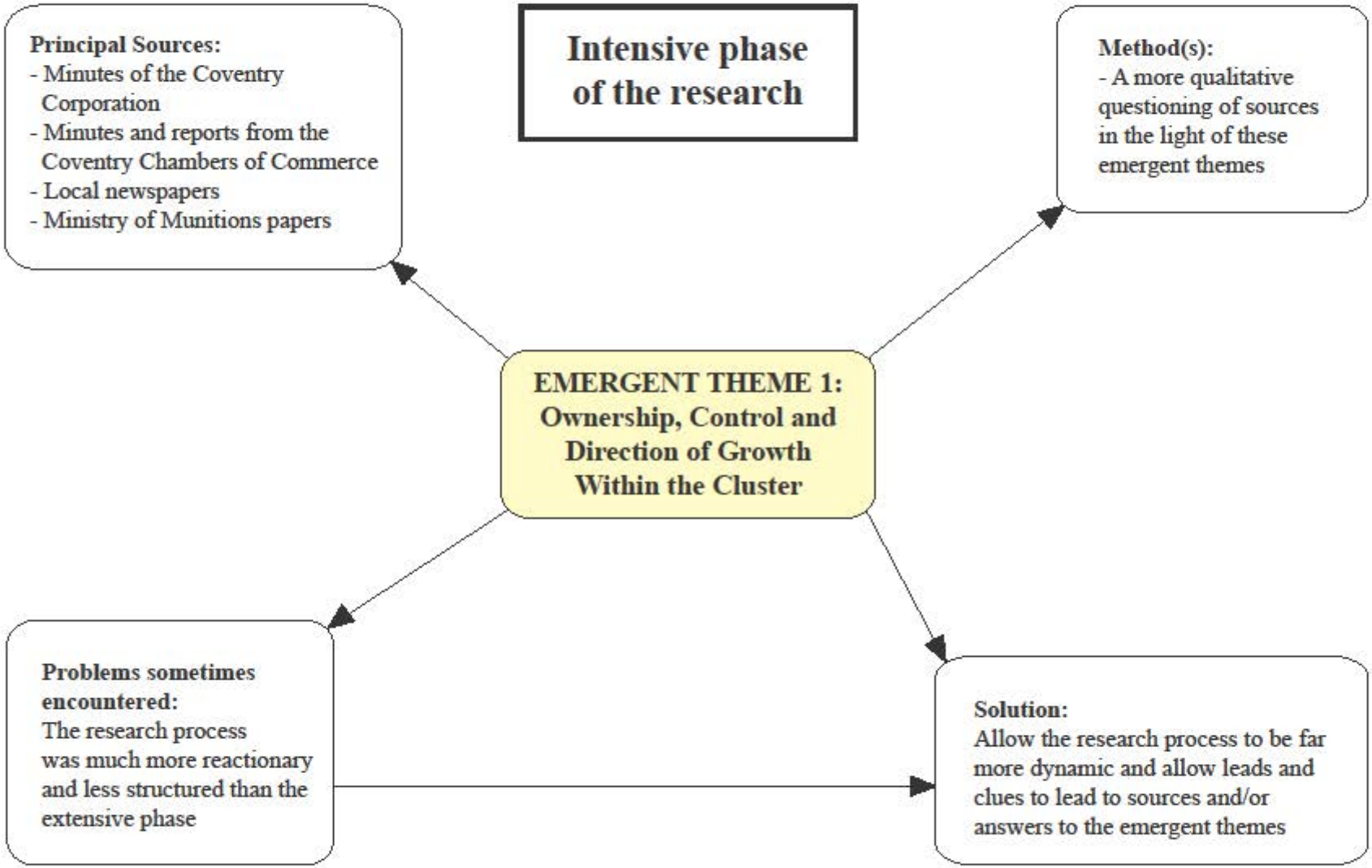

Extensive phase of the research
Principal Sources:
- Trade directories
- Commercially available maps
- Printed Ordnance Survey maps
- Digitised Ordnance Survey maps
- Building plans
- Contemporary A to Z street index for the city
Method(s):
- Cross-checking all the various information presented on the maps and then reconciling this with data extracted from a contemporary A to Z street index and various historical trade directories
STAGE 4:
To identify their location and map those firms over three time periods of the First World War
Problems sometimes encountered:
Location of firm premises unclear
Solution:
- Combining the information in trade directives with maps of various streets and counting the number of properties along a street or clockwise within a court behind a street until the correct firm location is found.
- Examination of photographs against maps of the city's streets to determine a factory's precise location

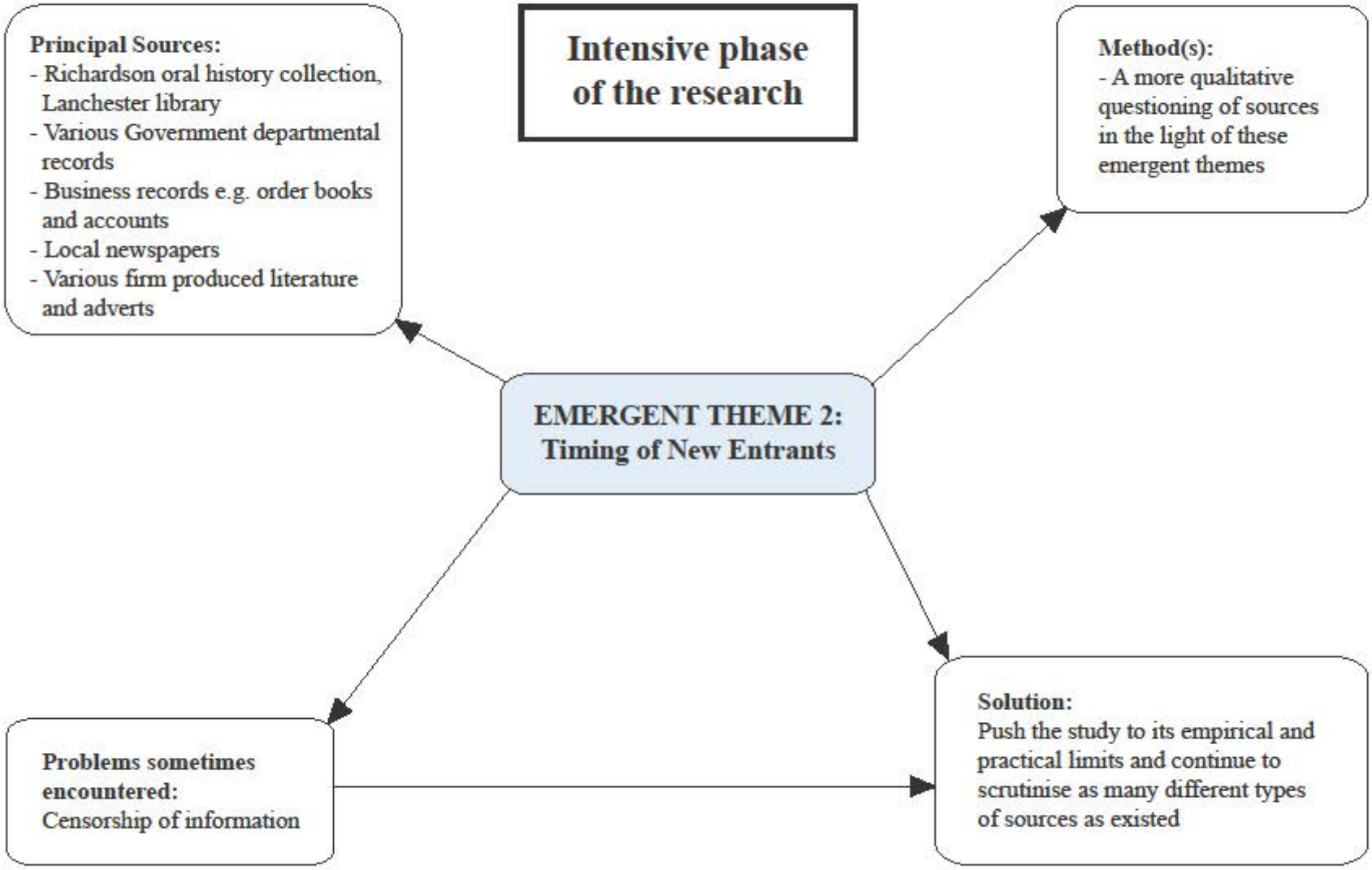
3.3 Intensive Research Phase

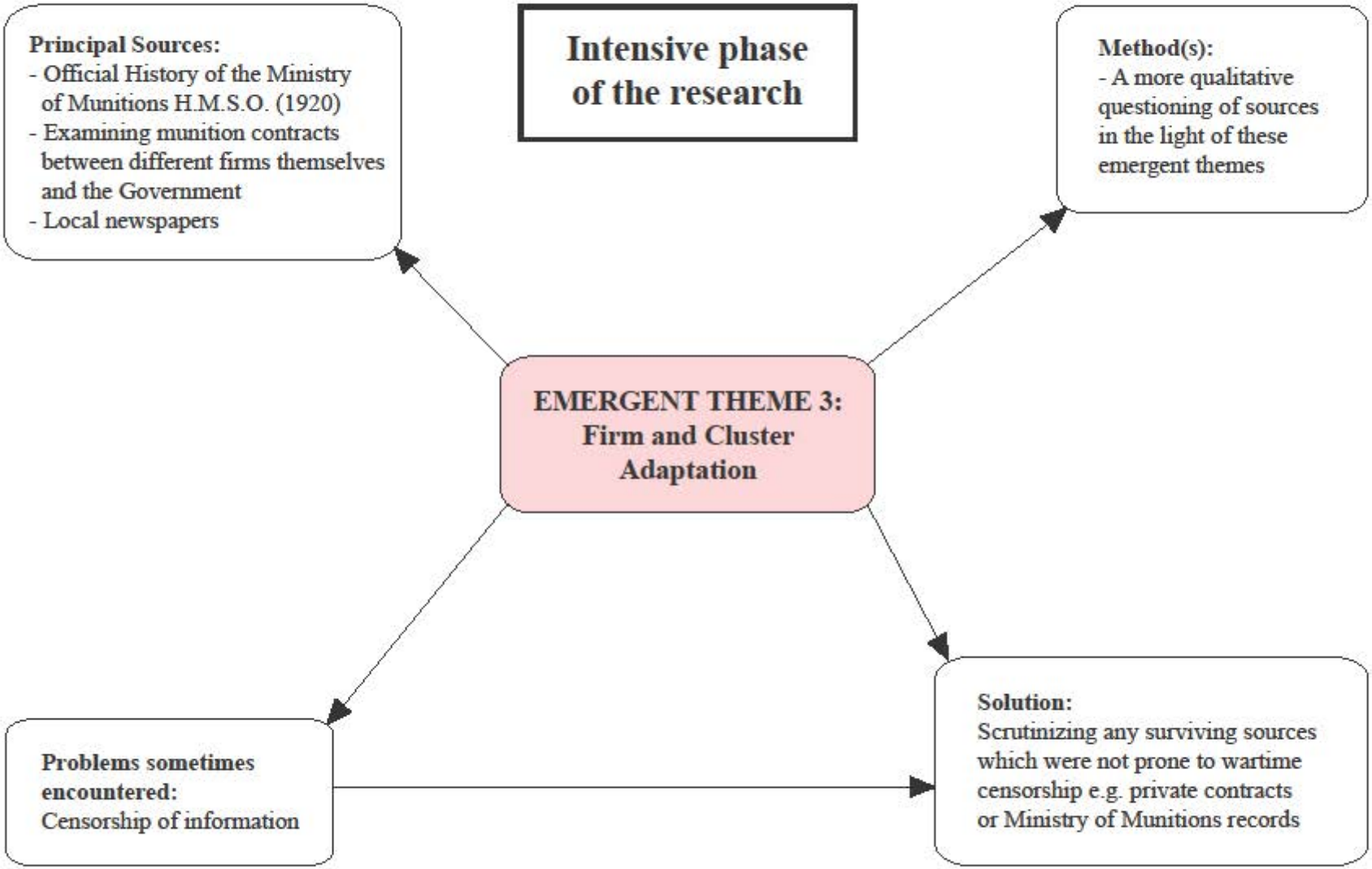
A second more qualitative, intensive phase was now needed in order to address objectives three and four of the research. This was to understand *how* firms operated within the cluster; what were the linkages between them and the support entities; how changes or expansion were implemented and also what instigated new entrants to join at the specific time they did. To achieve this, the study followed Porter's (1998) suggestion that to understand how a cluster operated important institutions and infrastructure linked to industry have to be identified. Furthermore the role of central and local government and any industrial regulatory bodies must also be examined[60].

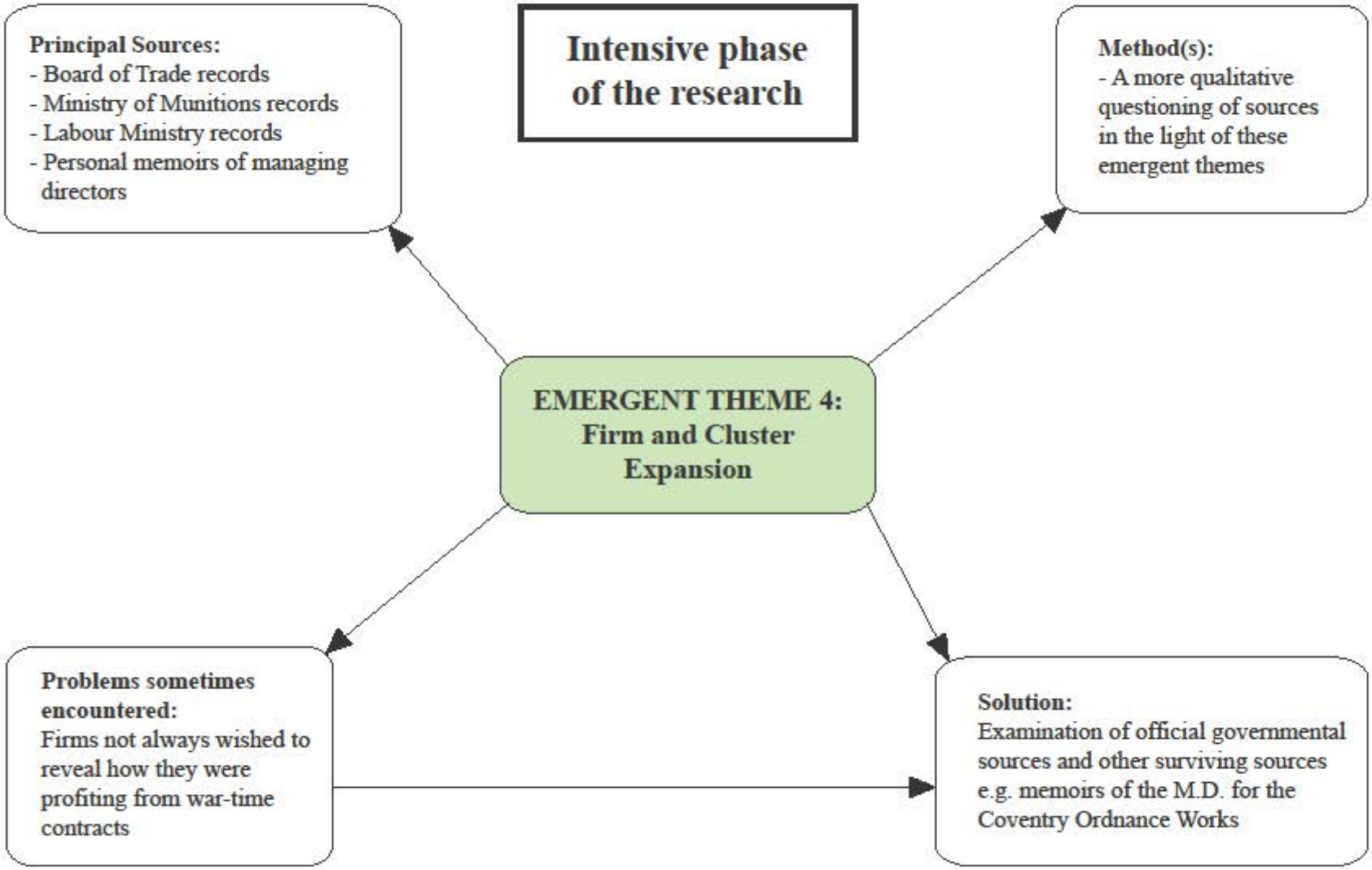
The rest of this section explores how these entities and/or actors were identified, mapped and the clusters operation further conceptualized by examining four "emergent themes" which arose from the earlier extensive phase. These were: the role of ownership, control and the direction of growth within the cluster; the timing of new entrants; and the adaptation of firms from peacetime manufacturing to munitions production. How these four themes were researched, using a more qualitative method is summarized by the following four diagrams overleaf. Each one also outlines principal sources and some of the problems and solutions encountered during this second intensive phase:

[60] Porter (1998) *On Competition* Chapter 7 Clusters and Competition


Intensive phase of the research
Principal Sources:
- Minutes of the Coventry Corporation
- Minutes and reports from the Coventry Chambers of Commerce
- Local newspapers
- Ministry of Munitions papers
Method(s):
- A more qualitative questioning of sources in the light of these emergent themes
EMERGENT THEME 1: Ownership, Control and Direction of Growth Within the Cluster
Problems sometimes encountered:
The research process was much more reactionary and less structured than the extensive phase
Solution:
Allow the research process to be far more dynamic and allow leads and clues to lead to sources and/or answers to the emergent themes


Intensive phase of the research
Principal Sources:
- Richardson oral history collection, Lanchester library
- Various Government departmental records
- Business records e.g. order books and accounts
- Local newspapers
- Various firm produced literature and adverts
Method(s):
- A more qualitative questioning of sources in the light of these emergent themes
EMERGENT THEME 2: Timing of New Entrants
Problems sometimes encountered:
Censorship of information
Solution:
Push the study to its empirical and practical limits and continue to scrutinise as many different types of sources as existed


Intensive phase of the research
Principal Sources:
- Official History of the Ministry of Munitions H.M.S.O. (1920)
- Examining munition contracts between different firms themselves and the Government
- Local newspapers
Method(s):
- A more qualitative questioning of sources in the light of these emergent themes
EMERGENT THEME 3: Firm and Cluster Adaptation
Problems sometimes encountered:
Censorship of information
Solution:
Scrutinizing any surviving sources which were not prone to wartime censorship e.g. private contracts or Ministry of Munitions records


Intensive phase of the research
Principal Sources:
- Board of Trade records
- Ministry of Munitions records
- Labour Ministry records
- Personal memoirs of managing directors
Method(s):
- A more qualitative questioning of sources in the light of these emergent themes
EMERGENT THEME 4: Firm and Cluster Expansion
Problems sometimes encountered:
Firms not always wished to reveal how they were profiting from war-time contracts
Solution:
Examination of official governmental sources and other surviving sources e.g. memoirs of the M.D. for the Coventry Ordnance Works

3.4 Summary: Methodology Matrix

Table 4 (overleaf) now summarises the entire methodological strategy employed to research Coventry's First World War armaments and munitions cluster:

Table 4: Methodology Matrix

Methodological Technique	Data Produced	Purpose of the technique in relation to the research	Research objectives addressed
EXTENSIVE RESEARCH PHASE			
Content analysis	Quantitative	To compile a list of engineering businesses in the city between 1914 and 1918 and to codify each firm into a specific firm typology.	Objectives 1 & 2
Scoping exercise	Archive Lists	To locate what sources existed for the city's engineering businesses in local, regional and national archives between 1914 and 1918.	
Extensive questioning of source material	Maps 1, 2 and 3	To reduce the business list of c.330 engineering firms by identifying which firms were producing armaments and munitions during the war. To pinpoint where there firms were located in order to position them onto a 1914 Ordnance Survey map.	
INTENSIVE RESEARCH PHASE			
Intensive questioning of qualitative sources in relation to emergent themes	Qualitative	To identify other actors, infrastructure or institutions important to the clusters operation. To then map those onto a 1914 Ordnance Survey map thereby completing the identification and mapping for this wartime cluster. By revealing these aspects of this historical cluster it may then be observed in a small number of cases how certain actors, institutions and infrastructure shaped the clusters operation and evolution.	Objectives 3 & 4

Having now discussed and developed a conceptual framework for this study and also devised a methodological framework the next chapter wishes to provide a contextual setting for the study.

Chapter 4 : The Industrial Development and Restructuring of Coventry Industry 1860's to 1914

This chapter outlines the empirical background and context to the study that follows. The city's rich historical past shall become evident and also how in its midst emerged a thriving industrial city which, by the early twentieth century, was the fastest growing city in the country. The city throughout remained dualistic where the old and the new seemed to co-exist although the later would come to dominate. A.E.W Mason, a Liberal MP for Coventry writing in 1912, described the city as a place:

> 'where a few steps will take you out of the thronged streets into some old garden quiet with the peace of ancient memories;....And round about these old places stand a ring of factories, where in good times, the lights blaze until morning and the whir of its machines never ceases from your ears. It is a city whose continuous life is written for all to see upon its buildings. Here kings and queens have tarried on their journeys; where Chambers of Commerce hold their meetings. From small and ancient beginnings it has been made by the activity of generations of men into a modern industrial city'[61].

The chapter shall begin by outlining Coventry's transition away from its staple industries into newer more 'modern' industries mainly light engineering based. Next, the important restructuring which occurred towards the turn of the twentieth century will be outlined and the nature and geography of the engineering industry and workforce by 1914 shall be revealed. Lastly the chapter concludes by outlining the most significant features of the industry and workforce before the commencement of hostilities.

[61] Mason (1912) *The Turnstyle*

4.1 Medieval guilds to silk ribbon weaving and watchmaking

Coventry's importance as an urban centre can be traced back to the medieval period when it was the first recorded settlement granted a Charter of Incorporation which effectively gave it city status in 1345[62]. In medieval England the economic life of the city depended upon the cloth trade. Much of this was exported abroad mainly through the ports of London, Bristol, Southampton, and Boston. Alongside this, the city had a small, but thriving metal-working, leather and fur trade and it would seem many of these industries operated through the form of craft guilds[63]. By the time of the nineteenth century, Coventry's economic structure was based on two long-established staple industries that of silk ribbon weaving and watchmaking, which were both craft industries.

Ribbon weaving was established in the city when the woollen-cloth trade became depressed and the city's textile workers turned their attention to producing silk-ribbons in the seventieth century. This was stimulated still further in the eighteenth century when Coventry received new ideas from France and the market demanded certain types of ribbons that fashion dictated. This industry was initially cottage-based, but from the 1830s onwards technological advances emerged in the form of the Dutch engine loom and later the Jacquard loom which encouraged production to become factory based. The weavers of Coventry often opposed this and both production systems of "cottage factories" and large factories seemed to co-exist.

By 1818 weaving provided employment for 4,973 persons out of a city population of 21,242 (in 1821). During the 1830s Coventry was at the centre of a weaving area of 13,000 looms supporting 30,000 people[64] and continued to expand until it reached its peak around 1861[65]. This industry enjoyed longevity and from 1765 to 1857, silk was the dominant industry in the city[66]. Despite this, it seemed to face many difficulties including intense foreign competition.

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[62] McGrory (2003) *A History of Coventry* p38.
[63] Ibid pp151-57
[64] *Victoria County History* Vol.8 section on ribbon weaving. Hereafter V.C.H.
[65] Searby (1976) *Watchmaking in Coventry*
[66] V.C.H. Vol8. pp162-89

By the 1860s the city's ribbon weaving had begun to collapse due to four things. First Cobden Treaty was made with France in 1860 by which their ribbons were now imported free of any duty. Secondly the U.S.A. put an import duty upon English ribbons, and, thirdly, ribbons started to go out of fashion. Fourthly an attempt was made to reduce wages in Coventry, which led to strikes, from which, the trade never recovered. By 1901 the industry had shrunk to a workforce of just 2,177 losing over 80% of its mid-century workforce. The distress which occurred in that time was more acute than at any time in the history of the city with half of Hillfields suggested to have become depopulated with row upon row of houses standing vacant[67]. This is highlighted in Table 8 (p.63) where the census figures for Coventry show between 1861 and 1871 silk ribbon weavers in the city halved and also the total population of the city decreased. Alongside Coventry's main trade of silk-ribbon weaving in the nineteenth century the city also developed as an important centre for watchmaking in Britain.

As far back as the seventieth century a local trade of watchmaking emerged initially to support the needs of producing and maintaining the clocks situated around the city. In the course of the next century it became firmly-established within the city, however, by 1817 an early downturn of only 14,000 watches were made, against 20,000 in the previous years, this being blamed on imports[68]. By the mid-eighteenth century the watchmaking trade stimulated the city's expansion with many of the watchmaker shops clustered in the growing Spon End and Chapelfield areas of the city. At this time Coventry's watchmakers were at their most prosperous and commanded a high reputation and the city had to rely largely on the watch industry as its principal source of income. This horological industry, however, was soon next in line to suffer as the market became flooded with cheaper machine-made watches from Switzerland and America.

The industry did however enjoy a brief resurgence in 1870-71, no doubt due to the Franco-German war then occurring, but throughout the remainder of the nineteenth century it declined in importance to the city's economy.

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[67] *Coventry Herald* 04/06/1897.
[68] Searby (1976)

It would still continue on into the twentieth century, mainly in factory form[69], but the city had to look elsewhere for employment and prosperity. Despite the distress and decline in Coventry watchmaking those that were employed would earn around £3 a week and have to only work 3 days a week in order to have sufficient to live on[70]. Alongside the development of these two important trades the city also enjoyed better links to its markets as by 1768 the Coventry Canal Company began to cut a canal from Coventry to Fradley Heath. This was later expanded to link it to Birmingham, London, Liverpool, Manchester and Oxford. The same connectivity was late in coming with the railway as the city did not enjoy the benefits of becoming a major railway centre and only a single line from London to Birmingham passed through, with the station having been opened, with the line, in 1838. Despite these improved forms of communication the Industrial Revolution was late in coming to this area of the West Midlands and Coventry demonstrated this pattern as she remained dominated by her traditional craft industries of ribbon weaving and watch making[71].The following table summarises the growth and the decline of Coventry's two most important industries of the nineteenth century:

Table 5: The Growth and Decline of silk-Ribbon Weaving and Watchmaking in Coventry 1841-1921

[69] Rotherham's, Errington's and the Coventry Watch Movement Company being the few remaining firms to continue watch production into the Twentieth Century on a significant scale.
[70] *Coventry Official Guide 1918* p27.
[71] Thoms & Donnelly (1987 and 2000). Batchelor (2005) also found this common in North Warwickshire for the nearby town of Nuneaton.

4.2 Watchmaking leads to cycle, motorcycle and motorcar production

The significance of watchmaking to the city was not just in the employment opportunities it gave to citizens when silk-ribbon weaving suffered it also gave the city a light-engineering sector. Initially this was in the form of manufacturing sewing machines when in 1863 the Coventry Sewing Machine Company was established to exploit the skill of the large body of trained watchmakers in the city[72]. Lack of capital and American competition made expansion for the firm difficult and although the company survived and extended its factory trade was slack towards the end of the 1860s. Therefore in 1869 the company was re-established as the Coventry Machinists' Company Ltd. This firm, under the guidance of James Starley, commenced to experiment with a new vehicle known as a "bone shaker" imported from France. Furthermore, Coventry Machinists' acted as a seed bed firm[73] and would attract wealth and prosperity to the city and ultimately make Coventry 'The Cycle Capital of the World'[74].

This marked the commencement of the cycle industry in Britain and as the machine was improved so to the industry germinated in Coventry and a large number of new firms commenced the manufacture of bicycles and tricycles[75]. Another important aspect of Coventry Machinists' was that many of the leading men who worked, or were apprenticed, there went on to setup in business locally themselves, namely, James Starley, William Hillman, Alfred Herbert and George Singer amongst others. With the introduction in the 1880s of Bessemer and Siemens-Martin steel, in place of wrought iron, which had been difficult to machine, it provided a further stimulus to the production of lighter, cheaper standardized parts. This along with the bicycle's design being perfected into the modern safety bicycle it increased in popularity and expansion continued in the city.

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[72] V.C.H.Vol8 pp. 162-89.

[73] Meaning the firm acted as a "hub" or a nucleus from which other 'spin off' trades, firms and individuals branched out from. See Lloyd-Jones & Lewis (2003) *Business networks, social habits and the evolution of a regional industrial cluster: Coventry 1880s–1930s*

[74] Hassell (2004) *The Coventry Machinists' Company Limited.*

[75] Other centres of cycle production were Birmingham and Wolverhampton, though Coventry had the greatest number of firms.

With the cycle industry prospering consequently a cluster of support industries, namely machine tools and bicycle component and accessories manufacturers developed in the city. This further attracted entrepreneurs to establish themselves in Coventry, such as Thomas Humber and Daniel Rudge, in the last quarter of the nineteenth century, who would both setup cycle firms of their own[76]. Thus by the end of the nineteenth century Coventry was a city of much social and economic change. By 1881 sixteen cycle manufacturers were noted as resident which had risen to seventy five during the boom years of the 1890s[77]. To establish these firms little capital was needed and production was often carried out initially in only modest premises.

This new cycle industry attracted much attention from the company promoting fraternity and therefore many of these firms were floated and capitalised, with Hooley and Lawson being the chief concern in this[78]. This left many of these firms with large capital investments generated from the sale of shares which they then utilised to erect and equip factories in Coventry to manufacture sufficient quantities of bicycles and components to generate a dividend for their shareholders. This had negative and positive spinoffs, firstly it helped stimulate employment and migration into the city and thus improve its prosperity[79], but it also meant that with a greater number of larger companies mass-producing bicycles the supply started to exceed demand and the collapse of the mid 1890s ensued. The continuity of Coventry's industrial development is highlighted by many factory premises becoming vacant and thus then being ideal for firms to adapt for the embryonic motor industry. Coventry had a pool of relatively skilled mechanics familiar with metalworking in the cycle trade which could be further exploited for this[80].

[76] Thoms & Donnelly (1985) p18.
[77] Lowe (1982) *A Guide to Sources in the History of the Cycle and Motor Industries* p6.
[78] Iliffe, Sir E. (1924) *Coventry Industrial History* Offprint JN670.
[79] See Table 8 where between 1870 and 1901 Coventry's population increased by 75 percent largely due to the prosperity that the booming cycle industry generated.
[80] For example several of Daimler's workforce were originally steam engine boiler makers having previously worked at Crewe in the railway industry and were later attracted to the city during the boom period of the cycle industry and then moved to Daimler's during the firms' formative years.

The existing firms which had survived the slump in the 1890s were able to further capitalise and expand their existing works or move to larger ones and these same firms were also in a position to realign production from cycles to motorcycles and later to motorcars or in some cases producing all three as well as sidecars.

The Daimler Motor Company entered the city and showed the way forward in 1896 and is regarded as the genesis of motor car production in Great Britain[81]. Having such a 'first mover' into the embryonic British motor industry locating in the city meant that whenever motorcar production was discussed in the late Victorian/Edwardian period Coventry's name would always be mentioned. By 1905 the number of motorcar manufacturers had reached 29 many of which were small and could not be considered mass production. These firms were producing virtually anything which needed a wheel, from bicycles, tricycles, side-cars, small cars, commercial vehicles and luxury cars for domestic and export markets. By 1913 many of the fragile companies had fallen by the wayside, but the city was still the centre of the motor trade with prestigious names such as Daimler, Rover, Rudge-Whitworth, Triumph, Singer, Swift, Rex, Lea-Francis, Humber, Standard and Maudslay to name only some of the leading firms. This allowed Alfred Herbert to point out in the same year that 'We in Coventry are largely concerned with motors'[82].

Almost piggybacking off the cycle and motor industries had emerged a cluster of component firms supplying the many needs of the assemblers for increased outputs. Firms such as The Coventry Chain Company, commencing in the city in 1896 by Alick Sargeant Hill[83], who had come from the watch trade, began to support the demand for roller cycle chains[84]. Another such firm was the Coventry Radiator Company which began initially as a plating company and then became one of the main radiator supplies for the motor industry by 1912[85]. A third example was that of the British Chuck and Tool Company established by one W.A. Oubridge in 1909.

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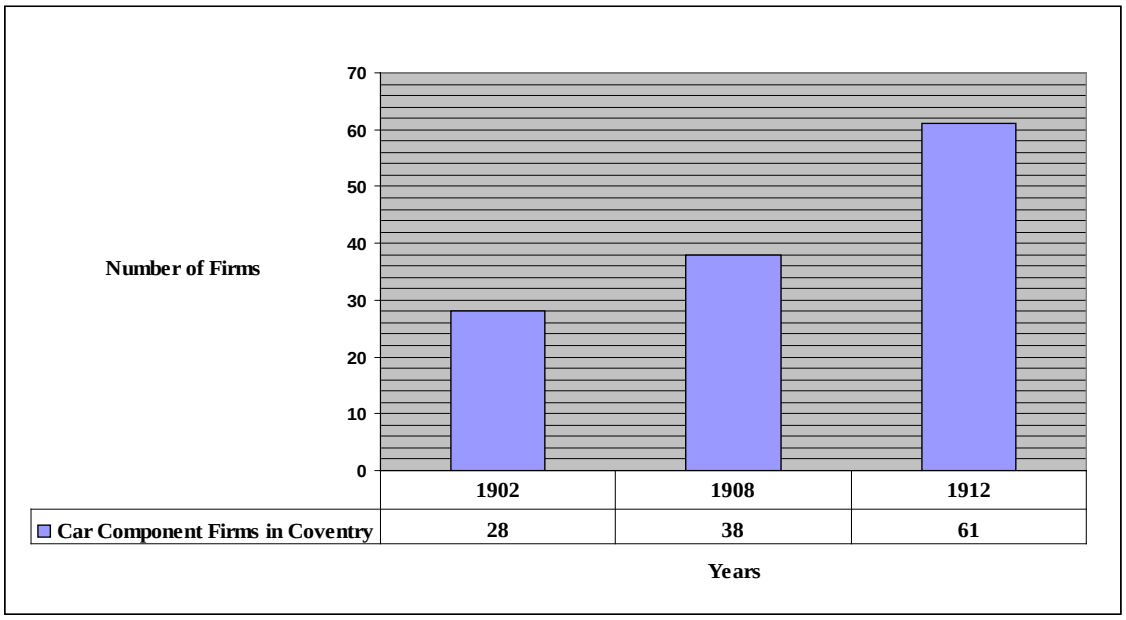
[81] For more information on Daimler's contribution in beginning the motor industry in Coventry see Nixon (1946), Smith (1972), Burgess-Wise et al. (1995), Long (1990 and 1995) and Bobbitt (2001) pp18-26.
[82] Prosser (1955) *Coventry: A Study in Urban Continuity'* p90.
[83] Who would later become Major of Coventry from 1916 to 1917.
[84] Tripp (1956) *Renold Chains*
[85] Richardson (1977) *The British Motor Industry 1896-1939* p93.

He found it more profitable to realign the firm into a specialist motor component firm in 1911 to concentrate on the manufacture of piston rings[86]. These 'support firms' were not just situated in Coventry as another firm, also linked to Mr Hill, was that of Bluemel Brothers situated in the nearby village of Wolston. They supplied to many of the Coventry's leading bicycle and motorcar firms with accessories and parts such as mudguards or sparking plugs. Broadly speaking most component firms were small concerns as it was noted that between 1895-1914 only three Coventry firms that of Dunlop, British Thompson Houston and Coventry Chain were public floated companies[87]. Figure 12 (overleaf) summarises the growth of this emerging support sector before the First World War:

Figure 12: The Rise of Motor Vehicle Component Firms in Coventry before the First World War



Sources: Beaven (1993 and 1994)

The emergence of drop forging can be seen as another support industry for Coventry's cycle and motor industries.

[86] Anon (undated) B.R.I.C.O. publication Coventry Archives.
[87] Beaven (1993 & 1994) Out of these three firms Dunlop had its origins and headquarters in Birmingham, British Thompson Houston was Rugby based and both had branch works or subsidiaries in Coventry. Thus leaving only Coventry Chain as the sole Coventry headquartered firm which was floated and sufficiently capitalised. This again reinforces that Coventry's many component firms up to 1914 were small scale and largely externally and privately financed.

Its beginnings in the city have largely to do with a Mr E.S. Brett, a pioneer of drop forging in Britain, who established Brett's Stamping Company in the 1890s. Due to improvements in forging pioneered by Brett's, the manufacturing costs for bicycles and later for the motorcar could be reduced. This was due to the fact hand forging metal was a slow, costly and not entirely satisfactory process, often wasting much metal owing for the need to leave a surplus for machining purposes. Machine drop forging obviated this, as each part produced became exactly like the one produced before, and there was also less wastage of metal[88]. The Stamping industry was also a near relative to drop forging and its emergence in Coventry also propelled the cities industrial growth in a similar manner, however, it was only utilised were there was a need for parts of very high repetition[89].

Within the city a leading machine tool firm, Alfred Herbert Ltd., emerged exploiting the demand placed on them from this expanding light engineering sector. The Coventry cycle manufacturer, for example, looked for labouring saving machinery to bend, form and produce steel tubes rapidly while later on the car manufacturer demanded improved machine tools capable of producing machined parts to very fine limits of accuracy and tolerance in the minimum time and with the least amount of supervision. In the later part of the nineteenth century the American and Continental engineers catered for this demand, for example, Alick Hill's first Coventry Chain machinery, used in his small Dale street premises for making cycle chains, had to be imported from the USA. Or for Coventry's few remaining watchmaking firms, such as Rotherhams, much of their machinery had to be imported from Switzerland[90].

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[88] Drop forging also allowed more complex manufacture where the number of parts ran to hundreds or thousands. Also as uniform materials of known strengths could be used, and the working temperatures regulated to a fine degree, it was then possible for the supplier of these forgings to give a very explicit guarantee to the cycle or car manufacturer. In turn they could then pass that guarantee of quality on to their customers in respect to a cycle frame or motorcar engine. Significant economies of scale occurred when any engineering products from the city's manufacturers could now be drop forged for the first time in large batches.

[89] *Coventry Official Guide 1915 &1918.* One of the main driving forces also stimulating a growth in Coventry stamping, pressing, drop forging and other general metal working firms was the city's car assemblers refocusing production towards producing small light cars made in higher numbers than previously. For example, Standard and Singer both took this direction between 1910 and 1914. This in turn put a greater emphasis on external motor component supply as larger production runs were now desired of standardised and sometimes interchangeable parts.

[90] C.A. PA1467/89/1-2.

How Coventry's growing machine tool production stimulated development in the cycle and later the motor industry is illustrated by the following example. In 1902 a machinist working on an 'old-fashioned' centre lathe, at Daimler, producing a component such as steel gear blanks would be allowed 10½ hours to complete each one. By 1914, in the same works, now could be found a row of automatic machine-tools which each could produce a similar blank, without much supervision on the part of the operator, in exactly 18 minutes! One semi-skilled operator could supervise the working of up to four of these machines at one time. Indeed, with this progress, the skilled craftsman was being swept aside by the semi-skilled machine operator and now it was the automatic machine tool which set the speed of production[91]. Alongside the reduced costs in labour saving and productivity brought about from this automation, machine tools also produced a precision of machined parts which would have been beyond that of any worker and especially in the never ending repetitious nature that was desired in these expanding industries.

Other industries to emerge in the city at the beginning of the twentieth century included electrical engineering firms with the largest concern being British Thompson Houston established in 1912 to produce electrical meters[92]. However, perhaps the biggest change for the city came in 1902 when for first time it became an important centre for armaments production. The famous Birmingham coach-building firm of Mulliner's merged and decided to relocate their activities to a tubing works in the northern Foleshill district of Coventry. This firm becoming Mulliner and Wrigley and was supplying gun carriages to the British Army. By 1905, Cammell Laird had taken complete ownership and with further financial backing from John Brown, and Fairfield Shipbuilding, the Coventry works was reformed as the Coventry Ordnance Works (C.O.W.)[93]. This move was prompted by a desire to break the duopoly held by Armstrong's and Vickers Ltd, in heavy naval armaments manufacture[94].

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[91] *Coventry Official Guide* 1915 and 1918.
[92] Price-Hughes (1946) *B.T.H.* p34.
[93] Trebilcock (1977) *The Vickers Brothers* p116 and Warren (1998) *Steel, Ships & Men* pp8-9.
[94] By the time hostilities commenced C.O.W. was a contractor favourably placed on the War Office and Admiralty lists which meant they would be one of the first firms asked to tender for munition contracts. H.M.S.O. (1920) *History of the Ministry of Munitions* Appendix VIII p112.

This firms' original intention was to break into the naval gun market, but it struggled to gain any significant orders for the first five years of its existence mainly due to it not been looked on favourably by the Admiralty or the War Office[95]. During this time the firm survived by manufacturing components for Coventry's motorcar assembly firms[96]. However things improved by 1910 and it started to secure government contracts and export orders which were accelerated by the arms race with Germany. One of the first significant contracts it was able to secure, before 1914, was for the manufacturer of 18-pounder gun carriages[97]. The Ordnance Works improved situation continued shortly before the war as their designs for a new 4.5-inch field howitzer were so successful it was adopted as the main field weapon for the British Army.

4.3 Restructuring within Coventry's economy and the pre-war character of its engineering labour force

It is, however, too simplistic to consider Coventry's industrial development merely as cyclical periods of growth and prosperity leading from one industry to another. Important restructuring occurred within the city during the third quarter of the nineteenth century which was located within the broader structural transformation in Britain between 1870 and 1914. Britain's economy at this time shifted from traditional trades of coal, iron, steel and textiles and Coventry followed this pattern by moving away from silk-ribbon weaving and watchmaking into industry mainly based around light engineering[98]. This narrow sector comprised a range of interconnected industries, including cycle, motorcycle and motorcar manufacturers, machine tool, electrical engineering and component firms. Significantly these were highly inter-dependent and the technologies and markets linking them were similar[99].

By the time of the 1911 census the city had grown by 52percent in the previous decade to 106,349 persons.

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[95] This was partly due the then Managing Director of the C.O.W., Mr H. H. Mulliner, who was looked upon with hostility and suspicion especially from the Admiralty after the 'We Want Eight And We Won't Wait' naval arms race scandal with Germany.
[96] Beaven (1994) p87.
[97] Hogg (1998) *Allied Artillery of World War One* p25.
[98] The Ordnance Works being really the only heavy industry within the city by 1914.
[99] Thoms & Donnelly (1987)

Of this total, 20,315 were recorded employed in the cycle and motorcar cluster of industries demonstrating its vital importance to the growth of the city[100]. The following table 6 (overleaf) now summarises how, by 1911, the employment pattern had transformed from the city's traditional industries into that centred on vehicle production, light engineering and metal working: THE FOLLOWING TABLE IS REMOVED FOR COPYRIGHT REASONS

* 2,830 or 73 percent of this total were Women. Comparing this to 1841; when the proportion of women and men in textiles was roughly equal, this shows that between 1841-1911 many of Coventry's male workforce, of employment age, were being drawn into the city's engineering and metal working trades. Furthermore, it shows how female labour persisted in Coventry's textile firms and was, outside domestic service, their main source of employment up to the First World War.
Note: The Coventry Census Enumeration District covered 4,147 acres which did not include the 1,900 acres in Coventry's outlying districts. Here a separate Enumeration District that of the Warwickshire Rural District is utilised for Census surveys. This means a proportion of population which would have worked in Coventry industry is excluded from these 1911 figures.

Source: Census Statistics Books AB312

[100] Census Statistics Books for 1911 AB312

By 1911, semi-skilled workers accounted for 45 percent of local engineering employees (compared to an industry average of 18 percent), blurring the traditional division between all-around craftsmen and unskilled labourers[101]. In this respect Coventry's engineering labour force did not confirm to a typical British pattern. The relatively inexperienced workers required for cycle and motorcar production were secured not by downgrading skilled engineers, but by recruiting unemployed craftsmen from older, depressed local trades (ribbons and watchmaking) and from migrants from the surrounding rural districts. Thus the traditions, techniques, and representatives of engineering craftsmanship never enjoyed the prominence in Coventry that they did in more traditional metal working centres such as Sheffield[102].

4.4 The geography of Coventry industry by 1914

The city by the early twentieth century can be seen as one of contrasts. It had a centre of interwoven narrow medieval streets lined with timber framed buildings with many overcrowded courts behind. It was in these locations that many of the early manufacturers had developed, especially the smaller concerns. Here space was very restrictive, but it was this medieval centre in districts such as the West Orchard where weaving premises would become vacant for the cycle and later motorcycle and motorcar manufacturers to establish themselves. There persisted well into the Twentieth Century strong watchmaking areas namely the central Spon End area and spreading out towards the South-West of the city into suburbs such as Chapelfields and Earlsdon. The northern suburbs of Radford, Foleshill and Longford formed a growth pole during late-Victorian and Edwardian England where new houses and factories began to be erected. This expansion was driven by firstly the bicycle boom, for example, Challenge Cycle, Coventry Eagle and the Riley Cycle Company all had factories there. Secondly it was the location where Britain's first motor firm was established, Daimler in 1896 at the Motor Mills and then by 1912 consolidated there with a second plant in Radford.

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[101] Hinton, (1973) *The First Shop Stewards' Movement*, p. 218.
102 Haydu (1991) *Between Craft and Class* p163.

White and Poppe, perhaps Britain's leading engine manufacturer before 1914, also had its works situated in the nearby Foleshill district. Finally it was this northern corridor where many of the larger component and machine tool firms also became established prior to the First World War. For instance, in Coventry's growing machine tool, drop forging and stamping sectors Alfred Herbert's Edgwick Foundry (1900), Webster and Bennett's Northey Road Works (1887), Sterling Metals, making castings also in Northey Road (1907), Albion Drop Forgings (1900), Brett's Stamping Company, and Brett's Patent Lifter Company (1890s) all could be found here[103]. So too could electrical engineers Morris & Lister and smaller component firms such as Condor Motor Fittings. Significantly this was also the location for the Coventry Ordnance Works which between 1906 and 1914 had become one of the largest employers in the city with a plant continually expanded between 1909 and 1914 when it began to obtain military contracts. This suggests that the northern corridor of Coventry, which had good access to both the main railway line and canal, was the main focus of industrial and urban expansion prior to the First World War[104].

4.5 Summary

This chapter has discussed the changing trades and industries that Coventry developed from its medieval origins up to the commencement of the First World War. It has discussed how the city moved from the cloth trade to silk ribbon weaving and watchmaking by the nineteenth century. After these two industries started to decline a newer industry began to supersede them that of sewing machines produced by the Coventry Machinist Company. This occurred largely because the city's watchmaking skills were transferable into sewing machine manufacture and this gave the city a light engineering base. By the late 1860s this same firm embraced the invention of the bicycle and along with many new cycle firms established within the city the technology was largely perfected and it became a commercial success.

[103] V.C.H. Vol.8 (1969) Foleshill p57-70.
[104] For example, a new railway 'loop line' was constructed for the ordnance works in 1914 and their works and that of Daimlers were well placed on two of the main northerly arterial roads and also had good access to the Coventry canal.

Alongside bicycle firms 'spin offs' comprising component suppliers and metal working establishments came into being to supply these assemblers who were pursuing a policy of profusion and expansion for both domestic and foreign markets. By the late 1890s the cycle industry was largely in a state of oversupply and the city embraced new technological inventions once again - that of the motorcar. Like the cycle industry beforehand the city prospered by exploiting the technological infancy and sought to perfect and make it commercially viable. Consequently the city grew still further and with the commencement of the twentieth century it was seen as one of the most progressive urban centres in Britain with unprecedented urban growth rates.
The most significant characteristics of Coventry industry before the commencement of hostilities is summarised thus:

- The industrial base was a narrow cluster of light engineering firms which by 1914 were producing inter-related products such as machine tools, cycles, motorcycles, motorcars, engines, motor components and electrical goods.
- From 1905 onwards the city established heavy engineering with the setting up of the Coventry Ordnance Works (C.O.W.) this meant for the first time the city was also a centre for armaments production.
- Broadly speaking the engineering labour force had a disproportionate amount of semi-skilled workers operating a high degree of automated machine tools in their workshops when compared to a national average.

Having now provided an empirical background and context for the study the next chapter two chapters discuss the research findings of the study.

Chapter 5: The Anatomy and Evolution of the Coventry Armaments and Munitions Cluster August 1914 – November 1918

The research findings are presented in two chapters. This chapter seeks to identify and map the First World War armaments and munitions Local Industrial Cluster (L.I.C.) at three time periods. The chapter is therefore split into three main sections. The first (section A) outlines the early cluster between August and December 1914. The second (section B) outlines the changes which occurred between April 1915 and December 1915. The third and final section (section C) outlines the cluster at the end of hostilities between January 1916 and November 1918.

Each of these three time periods are further sub-divided into four sub-sections. The first looks to place the cluster within the changing historical context of the war. The second then describes the geographical patterns and structural changes noted within the cluster. A third section discusses the change in ownership and control within the clusters operation and a fourth and final sub-section then gives a brief overview of significant armaments and munitions that the Coventry cluster was tasked to produce. The chapter then concludes with a summary of the key changes within the cluster between August 1914 and November 1918. This chapter therefore accomplishes objectives one and two of the research.

Section A – Coventry's Armaments and Munitions Local Industrial Cluster August 1914 - December 1914

5.1 Historical Context

With the invasion of Belgium, Britain declared war on Germany on the 4th of August 1914 as she had signed the Treaty of London in 1839 guarantying her neutrality. Thus the First World War began with Britain, France and Russia forming the Triple Entente against the Central Powers of Germany and Austro-Hungary. Both sides were misguidedly optimistic and Britain expected only a limited war in which she would rely upon her naval superiority only. On both sides political and public opinion was that it would be over by Christmas. However, it had been a century since Britain had fought a war against a major European power. During that time she had fought the Crimean and Boer wars, but neither had necessitated fundamental readjustments to her economy. Therefore there was no experience of the economic stresses and industrial efforts needed for a modern total war[105]. To be in a position to support her French ally Britain needed to recruit a large new army which pre-war was dwarfed by both the French & German standing armies. Thus on the 7th of August Field-Marshal Lord Kitchener instigated a policy of voluntary recruitment which by the end of 1914 had produced slightly over one million men for the British Army[106].

This rapid increase meant that during 1914 supplies for the British Expeditionary Force already in France, the Royal Navy and this growing British Army at home had to come from the royal arsenals and established armaments and munitions firms on the approved War Office List[107]. Lloyd (1924) for example, suggested the government's aim was to 'rely on private enterprise and the laws of supply and demand'; 'a prosperous state of trade, regular employment at good wages and high profits for the Revenue to tax and the Treasury to borrow, were regarded with good reason as essential conditions for the successful prosecution of the [early]war'[108].

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[105] Pollard (1973) *The Development of the British Economy 1914-1969*, p42.
[106] Dewey (1984) *Military Recruiting and the British Labour Force during the First World War* p199 and Hartigan (1999) *Volunteering in the First World War: The Birmingham Experience* pp167.
[107] Of which in Coventry, only the Coventry Ordnance Works was a contractor on this list.
[108] Lloyd (1924) *Experiments in State Control* p22-23 & p261 emphasis added.

War on the scale that quickly became apparent meant that almost immediately some intervention was inevitable. Therefore, under powers derived from an Act passed at the time of the Franco-Prussian War in 1871, the government commandeered the railway network on the 4th August 1914[109]. Despite these exceptions Government policy at this early war stage was reactive and to intervene only at selected points in the economy as it was still committed to the doctrines of free trade and individualism. To implement this 'business as usual' policy the War Office or the Admiralty were given by the Treasury virtually unlimited spending power and it was hoped that by offering sufficiently high prices, the supplies of armaments and munitions would be forthcoming.

5.2 Geography and Cluster Structure

Map1 (overleaf) depicts the early war cluster of armament and munition firms and the support institutions and infrastructure serving their needs by December 1914[110]. It is further complemented with Table 7 which provides a summary of each firm, their address and the munitions (if known) they were producing at this time. In addition, the key support institutions and infrastructure, serving their needs are outlined.

[109] May (1996) *An Economic and Social History of Britain 1760-1990.* p335.

[110] Referring to the Legend on Map 1, firms were categorized into small, medium or large firms by the size of their workforce: A small firm being less than 100 employees; a medium sized firm being between 101 and 500 employees; and a large firm being one which possessed 501or more. NA MUN5/101/360/16 July 1915 - July 1918 was a useful national survey which gave the number of employees for some local firms during the war. For firms not included, other archival sources such as company records, histories or thesis and building plans were used (see bibliography). Where no figure could be located, an approximation of workforce size was assigned by examining the size of a firm's premises and the nature of the work they were undertaking from mainly map, building plan and photographic evidence.

THE FOLLOWING MAP 1 HAS BEEN REMOVED FOR COPYRIGHT REASONS

Table 7: Coventry's Armaments and Munitions Cluster by December 1914

Firms

No	Company Name	Factory Address	Principal Trade	Early War Armaments and Munitions Production
10	Brett's Patent Lifter Co. Ltd.	Foleshill Works, Spring Road	Drop Hammer Manufacturers	Patent Hammers, Power Presses, Furnaces & other installation plants together with accessories and spare parts
13	British Chuck & Piston Ring Co.	Sandy Lane (Right-hand East-side after bridge)	Chuck & Piston Ring Manufacturers	Producing Piston Rings for Motor Vehicle Engines & also Piston Castings, Shackle Bolts & Gudgeon Pins.
16	British Thompson-Houston Co. Ltd.	Lower Ford Street	Magneto's & Electrical Engineers	Magnetos for vehicles & aeroplanes
23	Charlesworth Bodies Ltd.	128 & 129 Much Park Street	Motor Body Builders	Rebuilt commandeered Coventry and other town & city's public transport Buses into War Department Lorries. Also manufacturing 100s of Ambulance Bodies, Staff Cars, Field Kitchens & Lorries for British & Allied Governments
25	Condor Motor & Fittings	182-184 Broad Street Garage	Engine & Aero Engine Valves	Aero Engine Valves & Aero parts from August 1914
36	Coventry Magneto Co. Ltd.	15a Union Street	Magnetos est. 1914	Magnetos, including repairing
42	Coventry Movement Co., Ltd.	Spon Street	Watch Movements & suppliers to White & Poppe	Delicate Aeroplane Parts, Motor Switches, Taps, Petrol & Oil Indicators, Grease Cups, Nuts & Bolts & other components
44 - 46	Coventry Ordnance Works Ltd.	Ordnance Works, 11 Ordnance Road	Armaments & Small Tool Manufactures	Fuses, Field Guns, Howitzers, Shells, Tubes & spare parts & B.E.2a,b & B.E.8 Aeroplanes
51	Coventry Radiator Co. Ltd	Raglan Works, Raglan Street	Motor Vehicle Radiators	Manufacturing heavy type Radiators for Army vehicles
60 & 61	Daimler Co. Ltd.	Motor Mills, Sandy Lane & Radford Works	Motorcar, Commercial Vehicle & Engines	Cars & Lorries of all types for Military use including around 1,000 Ambulances & Staff Cars B.E.2c Aeroplanes and Gnome and R.A.F.1a Aero Engines
76	Herbert Alfred Ltd.	St. Thomas Villas, The Butts	Machine Tool Makers & Iron founders	Machine Tools such as Capstan lathes for Russian Government and various types for the British Government
77	Herbert Alfred Ltd.	Edgwick Works, Canal Road, Foleshill		
78	Hazlewoods Ltd.	Albion Mills, 52 West Orchard	Motorcycle & Combination Manufacturers	Combination Motorcycles, mainly for Colonial war service
86	Humber Ltd.	Humber Works, Stoke	Cars, Motorcycles & Engine Manufacturers	Field Kitchens & Bicycles
95	Maudslay Motor Co. Ltd.	Parkside & Quinton Road	Cars & Commercial Vehicles	Motor Lorries for the War Office
96	Middlemore & Lamplugh Ltd	87-89 Little Park Street	Cycle Saddle & Mudguard Manufacturers	Supplying Leather items to firms and the War Office
101	Morris & Lister Ltd	Carlton Works, 250 Lockhurst Lane	Electrical Engineers & Magnetos	Magnetos to the Motorcar firms
102	Morton & Weaver	137 & 139 The Gear Works, Cox Street	Engineers & Machine Tool Makers,	Engines, Gauges, Machine Tools & Small Tools
106	Pass, Thomas Ltd.	48 West Orchard & 101-102 Little Park Street	Motor Body Builders	Government Transport Wagons, 5ton Self Contained Trailers, Ambulances & Service Cars
112 & 113	Randle Radiator Co.	Nelson Street (1914) & Mile Lane, Cheylesmore	Radiators	Radiators for Maudslay's & other trucks
116 - 118	Riley Motor Co. Ltd	City Works, St. Nicholas Street & Cunard Works, Aldbourne Road	Motorcycles & Motorcar Manufacturers	Engines and Wire Wheels for Daimler, Vauxhall, Crossley staff cars
124	Rover Cycle Co. Ltd	Fleet Works & St. John's Works, & Reliance Foundry, 42 Spon Street	Cycles Manufacturers	1000 Bicycles for the War Office & 1000 for the Post Office
127	Rudge-Whitworth Ltd.	Rudge Works, Crow Lane & 34 Spon Street & 36 Hertford Street	Cycle & Motorcycle Manufacturers	400 Motorcycles for the Russian Army. (9th -20th Oct.1914) & 400 Motorcycles for the Belgium Army (1914-early1915)
133	Siddeley-Deasy Motor Co. Ltd	51 Parkside & 128 Much Park Street (Experimental work at Charlesworth Bodies)	Motorcar & Engine Manufacturers	Stoneleigh Lorries, Field Kitchens & Siddeley-Deasy 18hp Ambulances
148 & 149	Triumph Cycle Co. Ltd.	Triumph Works, Priory Street, Much Park Street & Dale Street	Cycle & Motorcycle Manufacturers	Motorcycles for the British Army
160	White & Poppe Ltd.	Lockhurst Lane, Foleshill	Engine Builders & Motor Engineers	Fuse 80 Bodies & 18pdr. Shell Sockets

Support Institutions and Infrastructure

Letter	Support Institution or Infrastructure	Address	Type of Institution or Infrastructure
C	Cycle and Motor Cycle Manufacturers & Trader's Union Ltd	The Towers, Warwick Road	Pre-war Business Support Institution
D	Labour Exchange	Lower Ford Street	Pre-war Labour Recruitment Infrastructure
E	Drill Hall	Queen Victoria Road	Resident Battalion's Army Hall
H	Coventry Chambers of Commerce	9 Masonic Buildings, Little Park Street	Pre-war Business Support Institution
L	Coventry & County Club	Queen's Road	Established Private Social Club

The Complete Early War Armaments and Munitions Cluster **30 Firms and Support Institutions or Infrastructure**

Cycle, Motorcycle & Motorcar Manufacturers = 9	Component Manufacturers = 11	Machine Tool Manufacturers = 4
Armament Manufacturers Total = 1	Metal Working Firms = 0	Support Institutions and Infrastructure = 5

Sources: See Bibliography

Map 1 reveals the late 1914 cluster was around 4sq. miles in size and included 25 engineering firms or slightly over 13 percent of the total number within the city. Out of this 25 it was dominated by cycle, motorcycle and motorcar assemblers and their component suppliers who together accounted for 80 percent of this early war armaments and munitions cluster. In terms of the types of firms immediately embracing munitions production, they tended to be the larger firms within their sector e.g. White & Poppe [160] (components and engine manufacturer), Rudge-Whitworth [127] and Triumph [148 & 149] (cycles and motorcycles) and Daimler [60 & 61] or Humber [86] (motor vehicles). Also they tended to be limited liability companies accountable to shareholders and governed by boards of directors. Their locations were mixed being both established pre-war premises in the inner-city and on the city's edge. There were also noticeable omissions of any participant firms in the South Western areas of Earlsdon and Chapelfields.

Isolated local clustering can be observed in certain areas including the Parkside area of the city where the Randle Radiator Company [113], Maudslay Motor Company Ltd. [95], Rover Company Ltd. [125] and the Siddeley-Deasy Motor Company Ltd. [133] were all located in close proximity. Map 1 also demonstrates that there were minimal support institutions and infrastructure specifically within the cluster to serve the wartime needs of firms. Therefore the cluster had to rely on the existing pre-war infrastructure, for example, the Labour Exchange [D] for labour recruitment.

5.3 Ownership and Control

In 1914 industrial mobilisation and co-ordination could only be instigated locally through formal entities such as the Coventry Chambers of Commerce (C.C.C.) [H] or the Cycle and Motor Cycle Manufacturers and Traders Union Limited (C.M.C.M.T.U.L) [C] or informally through the Coventry and County Club [L]. Arising from the Chambers of Commerce, one immediate step was the formation of a Coventry Emergency Committee (C.E.C.) to deal with 'situations that may arise from the war'.

It comprised an executive committee and reporting to this executive committee were five ward committees and numerous other sub-committees covering such things as distress, insurance, education and labour supply. What this meant to the forming and operation of the cluster at this time was minimal intervention into the business activities of firms, both for those turning to armaments and munitions production and those continuing with their private work. In essence the early war armaments and munitions cluster had weak local and national control and firms were left to either carry on manufacturing for their peacetime customers and markets or to seek war-work if they could capture any[111].

5.4 Armaments and Munitions Production

Coventry industry was recognised as an important supplier for any forthcoming war as two days before war was declared meetings were held in the city between War Office officials and the local motor manufacturers. Arrangements were made with these companies to supply large quantities of cars and motor cycles from their stocks[112]. These early arrangements were to provide vehicular transport the newly mobilizing army to reach France and to keep them supplied. Figures 13 and 14 (overleaf) entitled 'Animated scenes at the Daimler works at Coventry consequent upon the declaration of war' and 'A fleet of Daimler chassis which were prepared in two days notice' depict how Coventry motor firms responded immediately:

[111] *Coventry Herald* (Hereafter C.H.) 4-5th September 1914. The full composition of this Committee and a discussion of its role are given in Chapter 6 section 1.3.
[112] Wilkins (c.1919) *Journal of the European War 1914-19.*

Figures 13 and 14: Motor Vehicle Requisition & Production 1914

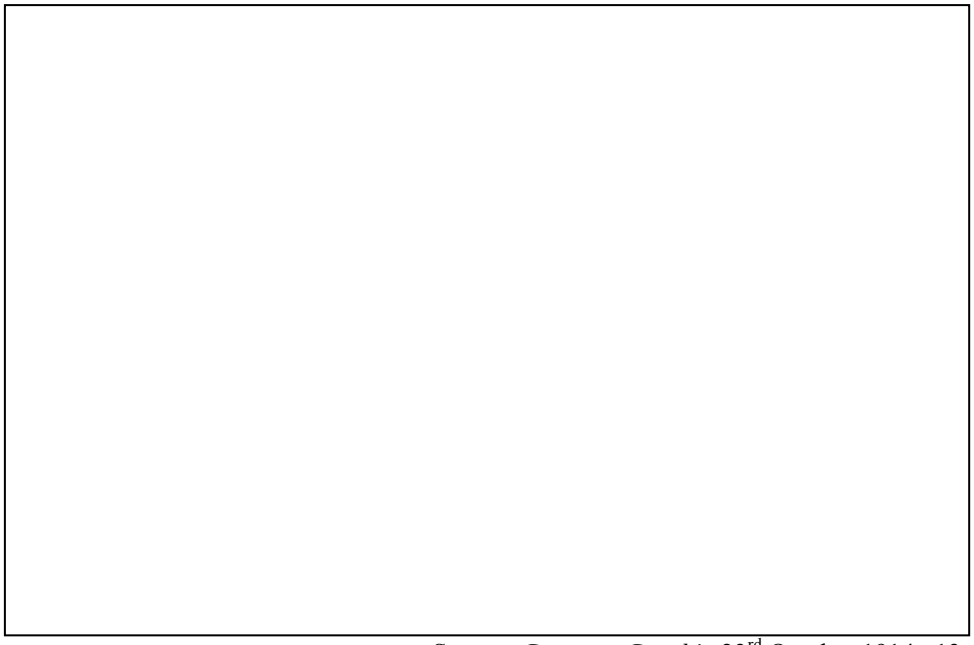
Sources: *The Motor* 18th August 1914 p86 and p88. These photographs appear to be taken at Daimlers Radford factory [61] on Map1.
Note: The top-right photograph (labelled 2) also appears to show War Office officials inspecting the Daimler lorries they are about to receive.

Immediate requisition, such as that depicted, meant these manufacturers had their domestic and export trade halted within weeks of war being declared. In the same month Daimler supplied 200 vehicles from their national network of depots, showrooms and repair shops and another 100 from their two factories in Coventry demonstrating immediately their significance to the war effort[113]. It is recorded that the British Expeditionary Force took with them 842 motorized vehicles to France during August 1914, 90per cent of which were requisitioned, undoubtedly many of these came from Coventry firms[114].

Similarly bicycle production also received immediate orders with one example being with the New Rover Cycle Company fulfilling two large government orders for their bicycles between August and October 1914, the first being for the War Office and second for the Post Office[115]. Coventry machine tool firms were also frantically meeting war orders both domestic and foreign. Alfred Herbert's two factories received acknowledgement in the local press that they had manufactured and dispatched a large consignment of capstan lathes for the Allied Russian Government. As the accompanying photograph shows overleaf the shortage of vehicular transport meant they had to be sent from the city by horse and cart. Also for British war needs the Brett's Patent Lifter Company was manufacturing and installed drop hammers at a torpedo factory in Greenock[116].

[113] Frost (1920) *Munitions of War*
[114] Fitzpatrick (1998) *The Bicycle in Wartime* p89.
[115] C.H. September 19th 1914, CG October 23rd 1914 and C.G. March 5th 1915. The Post Office order was to replace their earlier requisitioned bicycles.
[116] *The Engineer* 30th October 1914 pp412-413

Figure 15: Capstan Lathes for the Russian Government 1914



Source: *Coventry Graphic* 23rd October 1914 p13.

Before the war Humber Ltd, the Coventry Ordnance Works and the Coventry Victor Company had all experimented with aircraft production but failed to make it commercially successful[117]. By June 1914 (2 months before war was declared) the Coventry Ordnance Works had received a small order from the Military Wing for 17 machines[118]. By August and the onset of war, the Daimler Company also established their production in the city. In that same month Britain possessed just 272 aeroplanes in service with the Royal Flying Corps (R.F.C.) and the Royal Navy Air Service (R.N.A.S) respectively[119]. This deficiency was immediately exploited by Daimler who opened into negotiations with the French Gnome Engine Company on the 7th August 1914 to manufacture their aero-engine under license in Britain. Having received a prototype engine from Hendon to dismantle, examine and copy by the end of September they had manufactured and assembled its 1,100 pieces and the first British Gnome aero-engine was manufactured in Coventry.

[117] Smith & Fry (1997) *Godiva's heritage* p64-66, Lewis (1962) *British Aircraft* & Smith (2004) *Warwickshire Airfield*
[118] N.A. AIR1/764/204/4/199.
[119] Dewar (1921) *The Great Munition Feat* Ch.8 pp187-188.

The firm also accepted orders on the 30th of August 1914 from the Royal Aircraft Factory to manufacture its R.A.F.1 engine and B.E.2c aeroplanes[120]. Once this new production was underway, Daimler was now fast becoming the leading commercial engineering firm in Britain to enter into aero-engine and aeroplane manufacture[121].

Before the war Britain had relied on supplies of high-tension magnetos from the Robert Bosch Company in Germany. With this supply now cut off, the motoring press and local institutions, such as the Coventry Chambers of Commerce, stressed the need to establish a British magneto industry to supply this vital ignition component[122]. British Thompson Houston (B.T.H.) [16] and Morris and Lister [101] immediately responded and entered into manufacturing magnetos copying the existing Bosch types[123]. In addition the small firm of Coventry Magneto was able to repair and adapt existing stocks to further increase the supply locally[124]. B.T.H received their first war order for 300 sleeve type magnetos from the War Office in November of 1914 and these would be particularly adapted for use in military aircraft[125]. Other motor component firms operated as they had been doing before the outbreak of war with them continuing on supplying radiators or piston rings to the automotive firms. However, it is likely these would now have been almost exclusively for military vehicles. One area of departure was for the city's motor body builders who were tasked with much urgency to convert a variety of civilian vehicles for war use. In this respect large numbers of Britain's public transport vehicles were commandeered and sent to Coventry for rapid conversion for military use[126].

At the beginning of hostilities, White and Poppe, unlike other component firms in the city, adapted and embraced munitions production immediately.

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[120] Hare (1999) *Aeroplanes of the Royal Aircraft Factory* Chapter 2.
[121] The proceeding Daimler story has been summarised from the following: Frost (1920), Nixon (1946), Smith (1972), Montagu & Burgess-Wise (1995) 'Sleeve valves go to War' and Long (1995) Chapter 5: *Daimler goes to war.*
[122] *The Motor* 25th August 1914 pp109-110, 1st September 1914 pp136-137, 22nd September 1914 p211 and Coventry Chambers of Commerce (C.C.C.) Minutes August 1914.
[123] M.R.C. MSS.242/BT/9/11
[124] C.C.C. Minutes October 1914,
[125] B.T.H. (undated) *Our Part in the World War* p52.
[126] *Coventry and its Industries: Official Handbook* 1918 p42.

On the eve of war they were noted to have a workforce of 350 which was manufacturing carburettors, light car engines (mainly for Morris Motors) and a War Office subsidy engines[127]. With the outbreak of war they began preparatory work such as drawing up operation sheets for the manufacture of fuse bodies and they overhauled and adapted their machinery and also tools and jigs were supervised and repaired. On the 24th of August the Newcastle firm of Armstrong, Whitworth & Company Ltd. sub-contracted to them an order to manufacture 10,000 type 80 Mk.V fuse bodies and the same number of 18pdr. sockets per week[128].

Therefore they ceased engine and carburettors manufacture and all their available space was given over to these new munitions contracts. In October the demand for fuse-bodies had increased to 25,000 each week, and alongside demands for a Subsidy engine program, space was now most congested in their Lockhurst Lane factory [160]. Inside machines were so tightly packed together it was described as impossible to walk through the machine shops without being splashed with lubricant. By December fuse-body demand had increased to 43,000 per week alongside 10,000 shell sockets per week and the firm noted their Transport and Progress department was bursting apart with stacked fuse-bodies, sockets and engine parts[129].

Activity was just frenetic at the Coventry Ordnance Works (C.O.W.) [44, 45& 46] where just before war was declared they were undertaking the manufacture of 4.5-inch field howitzers for the Canadian government and now were receiving numerous additional contracts. As Table 8 summarizes their resources were geared to fulfilling early contracts for fuses and many more howitzers for the War Office. Additionally they received contracts to produce Royal Aircraft Factory B.E.2c aeroplanes for the first time:

[127] *The Limit*, and Hassell (2003) *White & Poppe Ltd*.
[128] Richardson (1977) *Twentieth Century Coventry* p78-79.
[129] *The Limit*

Table 8: Coventry Ordnance Works (C.O.W.) Armaments and Munitions Contracts 1914-1915

Date	Contract No.	Armament or Munition	Price	Quantity	Delivery Rates (per week)	Delivery Dates
09.04.1914	Canadian Government	4.5" Howitzers, cartridges, shells & stores	£288.6.8d	24*		Half by 31.03.1915, remainder by 31.03.1916
15.8.1914	F/2288	Fuse No.80	£60.0.0 per 100	116, 000		
24.08.1914	F/2338	Fuse No.82	£75.0.0 per 100	30, 000		
13.10.1914	G/1653 & G/1661	4.5" Howitzers	£2329.10.0 total per Howitzer	200	5 increasing to 12	13.13.1914-10.05.1915
13.10.1914	G/1719 & G/1728	4.5" Howitzers	£2429.10.0 total per Howitzer†	100	at least 12	10.05.1914-31.06.1915
28.10.1914	75/7/9403	Fuse No.80	£65.0.0 per 100	150, 000		
29.10.1914	F/2544	Fuse No.82	£85.0.0 per 100	50, 000		
30.10.1914	G/1748	4.5" Howitzers	£2429.10.0 total per Howitzer†	150		
11.01.1915	94/G/32	4.5" Howitzers and spares	This was a higher price than G/1748	200		

† The price was increased by £100 as this extra money was sanctioned for additional plant

* Orders placed by the War Office & Ministry occupied the whole of C.O.W.'s capacity and this order was transferred to the Imperial Government.

The Orders for ammunition and stores were cancelled on 02.01.1917.
The fuses, however, were delivered to the War Office and the guns to the Ministry during 1916.

Sources: NA MUN7/137, MUN5/373/1200/1, H.M.S.O. (1920) *History of the Ministry of Munitions* Pt. 1 Chapter III p84.

Section B – Coventry's Armaments and Munitions Local Industrial Cluster April - December 1915

5.5 Historical Context

As the War continued on into 1915 the policy of 'business as usual' and non-industrial intervention failed to meet the military demand, particularly for munitions. In fact deficiencies in munitions supply began with the very first recruiting drives of the war during late 1914 and progressively got worse as the army grew in size and offensive followed offensive. By March 1915, political pressure for the physical control of British industry became overwhelming when after the failure of the Battle of Neuve Chapelle, Colonel Charles Repington, a war correspondent with *The Times,* reported: 'We had not sufficient high explosive to level his parapets to the ground, after the French [and German] practice....The want of an unlimited supply of high explosive [shell] was a fatal bar to our success'[130]. This battle report highlighted the lack of capacity in British industry which was severely hampering Britain's ability to wage the type of artillery warfare that was now necessary. The blame was laid at the feet of the War Office and in particular Lord Kitchener the Secretary of State for War.

Therefore a 'shells crisis' scandal ensued. It became apparent that the over-reliance on the already existing armament firms was a critical error: 'the Army ought to have received by May 15th [1915], according to contract [from the armament firms], 481,000 H.E. 18-pounder shells. Instead of that, only 52,000, or very little more than one-tenth of the whole, were delivered'[131]. This was to have a profound impression on public opinion in Britain. As a result the Liberal government fell on 25th May 1915 and a new coalition government established (under the continuing Prime Minister Herbert Asquith).

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[130] *The Times* 04-05-1915 emphasis added. For an in-depth discussion on the 'Shells crisis' see George (1933) Vol.1, H.M.S.O. (1920) *Official History of the Ministry of Munitions* Vol.I & Dewar (1921) *The Great Munition Feat*

[131] Prime Minister Herbert Asquith speaking on 03-06-1919 as cited in Dewar (1921) p32, emphasis added.

Within the government a complete reorganisation of military procurement and industrial organisation was set in motion by creating a new department, the Ministry of Munitions (M.O.M.), and its responsibility handed to David Lloyd George.

From its inception Lloyd George saw that this new Ministry needed increasing control into all areas which the previous organisation had failed to come to terms with. One of the first and most important for an engineering city such as Coventry was the problems of a shortage of male workers in the engineering trade. To remedy this shortage their recruitment into the army was blocked and skilled men in engineering firms became a 'protected' occupation via a system of exemption badges. Having stopped the exit of the most valuable section of the country's workforce, something had to be done to facilitate an expanded munitions industry[132]. To this end Lloyd George accomplished an agreement with the representatives of the trade unions who now would permit labour 'dilution'. This was the substitution of skilled labour with semi-skilled or unskilled men and women and the unions also relinquished, for the duration of the war, other trade union practices which might have restricted output. These included the right of the worker to leave his/her job without the permission of the firm and any right to strike was replaced by arbitration. In return the trade unions obtained a guarantee that these powers would be restored at the end of hostilities and also that they could only be enforced in government "controlled establishments"[133].

By September 1915 the Ministry pushed forward this policy with all haste and already had 715 of Britain's main engineering companies as "controlled establishments", 14 of which were in Coventry. By utilising this form of centralised 'top down' control, the Ministry now had an unprecedented degree of economic control. It would now also be possible for them to build new national factories to manufacture shells and fuses in unprecedented quantities.

[132] Pollard (1973) p44-45

[133] This term simply meant that the factory or firm was commandeered by the Ministry of Munitions and therefore prohibited to undertake any private work. Thus its entire labour force and machinery were dedicated to munitions contracts and furthermore no one could leave without acquiring a leaving certificate. Generally speaking the more valuable to the war effort the firms output was the sooner it became a "controlled establishment".

They further had the power to draw into this expanding munitions industry semi-skilled and unskilled labour particularly women. These powers were enforced by numerous Acts of Parliament including the 1914, 1914 Consolidation and 1915 Defence of the Realm Acts, the Shells and Fuses Agreement, 5th March 1915 and the Ministry of War Act 1915 all of which are summarized in Annex 2-5.

5.6 Geography and Cluster Structure

Map2 (overleaf) depicts the mid-war cluster of armament and munition firms and support institutions and infrastructure serving their needs by December 1915. It is further complemented with Table 9 which provides a summary of each firm, their address and the munitions they were producing at this time[134]. In addition, the key support institutions and infrastructure, serving their needs are outlined:

map 2 has been removed for copyright reasons.

[134] The type of munition being produced is only given in Table 12 if this could be ascertained. Further if the munition type being produced had changed since Table 10 any new products are also given.

Table 9: Coventry's Armaments and Munitions Cluster by December 1915

Firms

No	Company Name	Factory Address	Principal Trade	Mid-War Armaments and Munitions Production
2	Albion Drop Forgings Co. Ltd.	Spring Road, Foleshill	Drop Forgers	Drop Forgings for Aircraft, Aero-Engines, Automobiles & Agricultural Manufacturers
4	Ariel Works Ltd	Ordnance Works site, Midland Road	Motorcycle Manufacturers	Motorcycles for British, Russian & Mesopotamia
5	Astley, John & Sons, Ltd.	18a Butcher Row	Rope & Twine Manufacturers	Equipments for troops
6	Auto Machinery Co. Ltd.	Hood Street & Read Street	Ball Bearings and Component Manufacturer	Ball Bearings primarily for Rotary Aero Engines & Shell Driving Bands
8	Bluemel Brothers	Wolston, near Coventry	Motor & Cycle Accessories	Supplying T Friction Tubes to the Coventry Ordnance Works Ltd.
10	Brett's Patent Lifter Co. Ltd.	Foleshill Works, Spring Road	Drop Hammer Manufacturers	Patent Hammers, Power Presses, Furnaces & other installation plants together with accessories and spare parts
11	Brett's Stamping Co. Ltd	57 Harnall Lane	Drop Forgings	Unknown
12	Britannia Foundry Co.	32 Cox Street & Well Street	Aluminium Founders & Engineers	Delicate Aeroplane Cylinders, 15-inch Shell castings, Aluminium Parts for Submarines, Phosphor Bronze Gun-Carriage Bearings and numerous other castings for the Admiralty & War Office
13	British Chuck & Piston Ring Co.	Sandy Lane Right hand East-side after bridge	Chuck & Piston Ring Manufacturers	Mass Producing Piston Rings for Motor Vehicles & Aero Engines & also Piston Castings, Shackle Bolts &Gudgeon Pins.
16	British Thompson-Houston Co. Ltd.	Lower Ford Street	Magneto's & Electrical Engineers	Magnetos for Vehicles, Aeroplanes and also Gauge Manufacture
17	Broadhurst R. & Co.	130 Queen Victoria	Wholesale Ironmonger, Tool Dealer & Motor Accessories	Motor Lamps, Tools & Accessories
18	Buckingham Engineering Co. Ltd.	Dover Street & Farmers Yard, Spon Street (Same Works)	Sidecars, Motorcars & Engineers	Incendiary Bullets for use in Machine Guns
19	Burbidge, H. & Son	Victoria Works, Vecqueray Street	Wood Turners	Wooden Transit Plugs (Fuse Hole 2") for 18pdr & 4.5 H.E. Shells
20	Bushill T. & Sons Ltd.	10,17 Cow Lane & Little Park Street	Printers & Box Makers	Paper cartons for food supplies sent to troops
21	Calcott Bros. Ltd.	165 Far Gosford Street	Cycle & Motorcar Manufacturers	18hp Chassis for Ambulances
23	Charlesworth Bodies Ltd.	128 & 129 Much Park Street	Motor Body Builders	Rebuilding commandeered Coventry and other town Buses & Public Transport into War Department Lorries. Manufacturing 100s of Ambulance Bodies, Staff Cars, Field Kitchens, Lorries for British & Allied Governments & Motor Bodies for Austin cars for Russian Government
24	Challenge Cycle & Motor Co. Ltd.	Challenge Works, 201-269 Foleshill Road,	Cycle & Motorcycle Manufacturers	Unknown
25	Condor Motor & Fittings	182-184 Broad Street Garage	Engine /Aero Engine Valves	Aero Engine Valves & Aero parts since August 1914
28	Coventry Acme Motor Co. Ltd.	Osborn Road, Earlsdon	Motor Body Builders & Rex Motorcycles	Stokes Trench Mortars
31	Coventry Chain Co. Ltd.	Chain Works, Spon End	Transmission Chains & Accessories	18pdr & 2.75-inch Shells for the Coventry Armaments Output Commitee & 1000s of Fuses & Wooden Transit Plugs (Fuse hole 2-inch) No.3 mk.II From October 1915
32	Coventry Gauge & Small Tool Co. Ltd.	Warwick Street, Earlsdon	Gauge & Machine Tool Makers	Gauges & Small Tools
33 & 34	Coventry Eagle Cycle & Motor Co. Ltd	4 Lincoln Street & 201-269 Foleshill Road	Bicycles & Motorcycles	Unknown
36	Coventry Magneto Co. Ltd.	15a Union Street & Fleetwood Works, Greyfriars Lane	Magnetos est. 1914	Magnetos, mainly repairing
39	Coventry Motor Fittings Co.	104-105 Far Gosford Street & Croft Road	Motor Accessories Manufacturers	Cast Aluminium Radiators for Heavy War Transport Vehicles for Daimler and other firms.
40	Coventry Motor Foundry Co.	Read Street, (North-side)	Manufacturers of Motor Castings	Unknown
42	Coventry Movement Co., Ltd.	Spon Street	Watch Movements & suppliers to White & Poppe	Delicate Aeroplane Parts, Motor Switches, Taps, Petrol & Oil Indicators, Grease Cups, Nuts & Bolts & other components
44 - 46	Coventry Ordnance Works Ltd.	Ordnance Works, 11 Ordnance Road	Armaments & Small Tool Manufactures	Filling empty primers manufactured through the COVENTRY ARMAMENTS OUTPUT COMMITEE. & Ministry of Munitions., Field Howitzers, Naval Guns, Shells & Fuses, B.E.2a,b, B.E.8a & R.E.7 Aeroplanes
48	Coventry Plating & Presswork Co. Ltd.	Lower Ford Street	Platers, Polishers & Pressworkers	Most likely undertaking the presswork, plating & polishing for radiators for Army vehicles for the Coventry Radiator Co.
49 & 50	Coventry Premier Ltd.	10 Read Street, Hillfields & 8 Lincoln Street	Cycles, Motorcycles & Motorcar Manufacturers	Unknown Munitions & Bicycles
51	Coventry Radiator Co. Ltd	Raglan Works, Raglan Street	Motor Vehicle Radiators	Making heavy type Radiators for Army vehicles
52	Coventry Repetition Co. Ltd.	Raglan Works, Canterbury Street	Component Manufacturer	Turnbuckles, Pins, Stream Line Wires, Fork Ends, Eye Bolts, Universal Joints & Propeller Bolts. Small Screws, Studs, Nuts, Washers, Special Bolts, Including the many important parts of an Engine, such as Connecting-Rod Bolts.
55	Coventry Swaging Co. Ltd.	White Friars Mills (Needle), Whitefriars Lane	Spokes, Nipples & Sewing Machine Needles	Unknown
60 & 61	Daimler Co. Ltd.	Motor Mills, Sandy Lane & Radford Works	Motorcar, Commercial Vehicle & Engines	Cars & Lorries of all types for military use. B.E.2c & B.E.12 Aeroplanes & Gnome, R.A.F.4a, R.A.F.4d & Beardmore 120hp Aero Engines
65	Dunlop Rim and Wheel Co. Ltd.	Alma Street North-side	Wheel & Rim Makers	4.5 H.E. Shells for the COVENTRY ARMAMENTS OUTPUT COMMITEE and wheel rims for Aeroplanes & Military Vehicles
66	Dunlop Rubber Co. Ltd.	Alma Street South-side	Motor Accessories Manufacturers	4.5 H.E. Shells for the COVENTRY ARMAMENTS OUTPUT COMMITEE and wheel rims for Aeroplanes & Military Vehicles
69	Farmer & Son	116 Queen Victoria Road, Right hand East side	Engineers & later Press Tools & Pressings	18-pounder H.E. shells for COVENTRY ARMAMENTS OUTPUT COMMITEE & Laminations for Magnetos
72	George Wilson Gas Meters, Ltd	Foleshill Road, Foleshill	Gas Meters, Thermal Heaters & Gas Stoves	Non-ferrous Castings in Aluminium & Gun-Metal specialised in and made for Motor, Aeroplane Engines, Gun Fittings, Shell parts & Mines
74	Gloria Cycle Co. Ltd	Between 12-13 Much Park Street	Cycle & Sidecar Manufacturers	Supplying Sidecars for Triumphs & also supplied for the War Dept. Gloria Pigeon carrying Sidecars for use in communications
76 & 77	Herbert Alfred Ltd.	St. Thomas Villas, The Butts & Edgwick Works, Canal Road, Foleshill	Machine Tool Makers & Iron founders	Machine Tools such as Capstan lathes for Russian Government and various types for the British Government
78	Hazlewoods Ltd.	Albion Mills, 52 West Orchard	Motorcycle & Combination Manufacturers	Combination Motorcycles, mainly for the Colonies
80	Hillman Motor Co. Ltd.	Humber Road	Motorcar Manufacturers	Unknown
81	Hillman Shell Factory (The)	Lower Ford Street	Shell Producers	High Explosive Shell Cases.
83	Hotchkiss et Cie	Artillery Works, Gosford Street (South-side)	Machine Guns Manufacturers	Machine Guns for the Admiralty, War Office & Ministry of Munitions & also supplying to Allied countries
86	Humber Ltd.	Humber Works, Stoke	Cars, Motorcycles, Engine Manufacturers	18pdr & 4.5-inch High Explosive Artillery Shells for C.A.O.C., French Mortar Bombs, Field Kitchens; Contract on the 30th August 1915 for 150,000 Gaines, Artillery Draught Poles; Aeroplanes Avro 504a/k & 100s of 'wicked-looking steel darts for throwing from aircraft'
87	I.F. Forester	"Halvetia", Albany Road (South-side)	Watchmakers	Chronometers for the Admiralty
88	Kalker, E. & Co.	23 Much Park Street (East-side)	Wire & Electric Cable Manufacturers	Shells from mid 1915 likely for the COVENTRY ARMAMENTS OUTPUT COMMITEE., No. IIA Special Magneto cables and Armoured Electric Lighting and High & Low Tension Ignition Cables For Automobiles & Aircraft
91	Lee F. & Co.	7 Dover Street, East side 1st & 2nd properties	Watch & Electrical Jewel Manufacturers	Jewels for Torpedoes, Ships Compasses & Electrical Meters
95	Maudslay Motor Co. Ltd.	Parkside & Quinton Road	Cars & Commercial Vehicles	Type 'A' Subsidy Lorries for the War Office, Post Office, The Great Western, Great Eastern, Midland & Great North of Scotland Railway Companies, Lever Bros. and others & Aero Engine Components
96	Middlemore & Lamplugh Ltd	87-89 Little Park Street	Cycle Saddle & Mudguard Manufacturers	Supplying Leather items needed for soldiers equipment to the War Office & Admiralty
97 & 98	Mills-Fulford Ltd.	Crown Works, Stoney Stanton Road, & Progress Works, 287 Stoney Stanton Road	Cycle & Sidecar Manufacturers	Supplying Sidecars for Officer Transport for the Royal Flying Corp & also listed as producing 'Armaments'
100	Montgomery Sidecars	Between 9-11 Lower Ford Street	Sidecar Manufacturers	Sidecars for the military & Triumph
101	Morris & Lister Ltd (later ML Magnetos)	Carlton Works, 250 Lockhurst Lane	Electrical Engineers & Magnetos	Magnetos for vehicles & aeroplanes
102	Morton & Weaver	137 & 139 The Gear Works, Cox Street	Engineers and Machine Tool Makers, & Early Aeroplane Manufacturers	Gauges, machine tools, small tools and gear cutting for the Allies. Also producing Victor Engines to be used as auxiliaries in aeroplanes and bombing sights for aircraf
103	ML Magneto Syndicate, Ltd.	Victoria Works, West Orchard	Magneto Manufacturers	Magnetos for vehicles & aeroplanes
104	Omega Cycle Works	Croft Road, north side 2nd property	Cycles & Motorcycles	Hotchkiss machine gun bodies
106 & 107	Pass, Thomas Ltd.	48 West Orchard & 101-102 Little Park Street	Motor Body Builders	Government Transport Wagons, 5Ton Self Contained Trailers, Ambulances and Service Cars. Also Bodies for Maudslay Motor Lorries
109	Pistons Ltd.	Far Gosford Street (North-side 1st property)	Pistons & Gudgeon Pins	Making same for Aeroplanes, Motor Lorries, Motorcars & Motorcycles in Iron, Steel or Aluminium
111	Priory Accessories (Spencer Bros. from 1918 onwards)	Priory Mill, Priory Street	Reed, Slay, Harness & Motor Accessories Manufacturer	Heavy-pattern steel slays for military web equipment
112 & 113	Randle Radiator Co.	Nelson Street (1914) & Mile Lane, Cheylesmore	Radiator Manufacturers	Radiators for Maudslay and other lorries & also for aeroplanes
115	Rex Motor Manufacturing Co. Ltd.	Earlsdon Works, Osbourne Road	Cars & Motorcycles	Stokes Trench Mortars.
116 - 118	Riley Motor Co. Ltd.	City Works, St. Nicholas Street & Cunard Works, Aldbourne Road	Motorcycles & Motorcar Manufacturers	Wire wheels for Daimler, Vauxhall, Crossley staff cars and other vehicles. Aero Engines and Components, including Pistons, and Riley Engines for Generator
120 & 121	Rotherham and Sons Ltd.	Gosford Street Works, Bayley Lane & 27 Spon Street (South-side)	Watch Manufacturers, Engineers & Motor Components	Supplying T Friction Tubes to Coventry Ordnance Works Ltd. Rifle Clips for cycles, Motor taps, Aeroplane parts, Mechanical Clockwork fuses, delicate fuse work for Singers, scientific instruments & various component parts
122 - 126	Rover Co. Ltd. & Rover Cycle Co. Ltd.	New Meteor Works, Rover Road. Helen Street, Foleshill. Fleet Works, St. John's Works, & Foundry 42 Spon Street	Motorcycles, Motorcar & Cycle Manufacturers	500 Maudslay Lorries & 1,781 Sunbeam Ambulance & Staff Cars & Spare Parts. (1915-18). Stokes Trench Mortars, Gas Shells, Fuses and Tank Transmissions. Bicycles for the War Office & Post Office, 18pdr. Shells & 4.5-inch High Explosive Shells
127 & 128	Rudge-Whitworth Ltd.	Rudge Works, Crow Lane, 34 Spon Street & 36 Hertford Street	Cycle & Motorcycle Manufacturers	Fuses, Rifle Bullets, Sidecars to the Belgian Army, Sidecar bodies for Italian mountain troops. Aerial Torpedoes of 500lbs to 50lbs. Floating Mines for use at sea, Artillery shells, and Machine-gun shields. Barbed Wire Cutters, Carburettors in Aluminium most likely for Aeroplanes. Water Pumps, Landing Gear and any Metal Fittings for the B.E.2 Aeroplanes. A few hundred Motorcycles for the Italian Military. Military Motorcycles also for Russia, Belgium, South Africa, Australia & New Zealand (during 1915-16). Detachable Wire Wheels for use in Crossley Ambulances, Staff Cars and Aeroplanes.
129	S. Alexander & Sons.	61 Allesley Old Road	Wholesale Watch Manufacturers	Watches for the Admiralty, War Office & Royal Aircraft Factory
131	Selson Engineering Co. Ltd	St George's Road	Machine Tools & Engineers	Shaping & Radial Drilling Machine Tools
133 & 134	Siddeley-Deasy Motor Co. Ltd	51 Parkside & 128 Much Park Street (Experimental aeroplane design work at Charlesworth Bodies)	Motorcar & Engine Manufacturers	R.E.7 Aeroplanes, R.A.F. 1a & R.A.F.4a Aero Engines, Stoneleigh Lorries, Field Kitchens & Siddeley-Deasy 18hp Ambulances & Cars for the War Office
135	Singer Motor Co. Ltd.	50-54 Canterbury Street, Hillfields	Motorcycle, Cycle and Car Manufacturers	Staff cars and Fuses No.80 & 131
136	Smith's (Thomas) Stamping Works Ltd.	Red Lane Works, Red Lane	Drop Forgers	1,500 Components for the Associated Equipment Company's 3ton Lorries. Paravanes for Minesweeping for the Admiralty.
138 - 141	Standard Motor Co. Ltd.	Cash's Lane Works, Bishopgate Green Works & Widdrington Road Works	Cycle & Motorcar Manufacturers	B.E.12 Aeroplanes, supplying Component Parts for 18hp Chassis for Ambulances & also Shell & fuse manufacture (some of which done in Leamington)
144	Sterling Metals Ltd.	Northey Road, Foleshill & 1 George Street	Iron founders	Motor & Aeroplane Castings
145 & 146	Swift Cycle Co. Ltd.	Cheylesmore Works, Cheylesmore Street & Quinton Works, Quinton Road	Cycle, Cars, Motorcycle Manufacturers & Motorbody builders	Bicycles to the Government & 18pdr. Shells for the Coventry Armaments Output Committee
147	Tooby, Adkins & Co.	41-42 Bishop Street	Leather Factors for the Motor Trade	Leather equipments for troops
148 & 149	Triumph Cycle Co. Ltd.	Triumph Works, Priory Street, Much Park Street & Dale Street	Cycle & Motorcycle Manufacturers	Gauges & 30,000 Motorcycles for the British Army. 2 ¼ inch Fuse-Heads and Primers & 2 ¾ inch large Shell Noses & Friction T. Tubes Mk.IV from August 1915 onwards
154	Ward, E. J.	Smithy, Spon End.	Blacksmiths	Producing 1000s of horse shoes for the Army
155	Waygood Otis Ltd. (Clarke & Mote from 1916 onwards)	Vulcan Iron Works, Well Street	Aluminium Founders	Unknown
156	Webster & Bennett Ltd.	Northey Road Works, Folleshill	Machine Tool Makers	Including lathes Duplex Boring Mills Profile-Milling Machines and Large Marking-Out Tables for Aeroplane Work
160 & 161	White & Poppe Ltd.	Lockhurst Lane Works, Foleshill & National Fuse & Filling Factory No.10/21, Holbrooks Lane	Engine Builders & Motor Engineers	Subsidy Engines for Lorries made at the Lockhurst Lane Factory and Fuse 80 Bodies, 18pdr. Shell Sockets, rings, caps and base plugs at both factories initially and then at Holbrooks only once fully operational
162	W.H. Jones & Sons Ltd.,	Holbrooks Lane (East-side 1st property after Foleshill Railway Bridge)	Building Contractors	Built a lot of extensions for local munitions firms, but manufactured 1000s of Ammunition Boxes & produced laminations for magnetos
164	Williamsons, H. & Co. Ltd.	Errington Watch Factory, Holyhead Road	Watchmakers	Watchmakers to the British Army.

Support Institutions and Infrastructure

Letter	Support Institution or Infrastructure	Address	Type of Institution or Infrastructure
A	Ministry of Munitions	14 Much Park Street (East-side)	Coventry office for the government Ministry of Munitions
C	Cycle and Motor Cycle Manufacturers and Trader's Union Ltd	The Towers, Warwick Road	Pre-war Business Support Institution
D	Labour Exchange	Lower Ford Street	Pre-war Labour Recruitment Infrastructure
E	Drill Hall	Queen Victoria Road	Resident Battalions Army Hall
F	Munition Works Bureau	St Mary's Hall, Bayley Lane	War-time office for Munition Worker Recruitment
H	Coventry Chambers of Commerce	9 Masonic Buildings, Little Park Street	Pre-war Business Support Institution
I	Radford Aerodrome Aircraft Acceptance Park No.1	Next to Daimler's Radford Factory	Aerodrome and proving ground for city's aeroplanes
K	Drapers Club	Drapers Hall, Bayley Lane	Established Private Social Club
L	Coventry & County Club	Queen's Road	Established Private Social Club
M	Coventry Armaments Output Committee	The Towers, Warwick Road	Local Co-operative Munitions Committee

The Complete Mid-War Armaments and Munitions Cluster — **98 Firms and Support Institutions or Infrastructure**

Cycle, Motorcycle & Motorcar Manufacturers New Entrants = 21, Total = 30	Component Manufacturers New Entrants = 25, Total = 36	Machine Tool Manufacturers New Entrants = 5, Total = 8
Armament Manufacturers New Entrants = 2, Total = 3	Metal Working Firms New Entrants = 11, Total = 11	Support Institutions and Infrastructure New Entrants = 5, Total = 10

Sources: See Bibliography

Map 2 reveals an expanded cluster by the end of 1915 now comprising an area of around 6.3sq miles and including an additional 65 firms. Out of 88 firms forming the cluster three-quarters were cycle, motorcycle and motorcar assemblers and their component suppliers. This is a continuance of the early war firm typology and demonstrates how the city's core sector was continually being mobilised. However, the mid-war cluster now contained a higher proportion of smaller firms. For example, new entrants included the small blacksmith of Ward, E. J. [154] and the engineers Farmer & Son [69]. Another change was that 11 metal-working firms where now producing armaments and munitions compared to zero in the early-war cluster. This sector, which included foundry, pressing and stamping firms, now accounted for around 12 percent of the total number of mid-war firms. Firms such as the Britannia Foundry Company [12] or George Wilson Gas Meters, Ltd [72], amongst others), were producing castings for a whole variety of munitions[135]. There were also some noticeable changes in location of some of the new entrants to the cluster. Four firms now appeared in the South West wards of Earlsdon and Chapelfields, and three more in the Western fringe of the city which were both previously areas devoid of munition firms. New isolated clusters of firms also appeared straddling two of the main Northerly arterial roads: the Foleshill Road and Lockhurst Lane.

Larger new entrants to the cluster were appearing in a variety of locations. One such company was the Ministry of Munitions No.10 National Shell Filling & Fuse Factory[136] [161 managed by White & Poppe]. This had to be accommodated to the North of the city boundary on land of the Warwickshire Rural District. Other large firms, such as the French machine gun manufacturer Hotchkiss et Cie [83] were able to take over and expand vacant premises in the city centre. Also at this time, numerous support institutions and infrastructural changes emerged within the cluster. These included the city's own Ministry of Munitions office [A] and a Munition Works Bureau [F] to help with labour recruitment.

[135] See Table 9 for the types of castings being undertaken.
[136] Later on in the war this name was changed to No.21 National Shell Filling & Fuse Factory as there was a number of faulty fuses from this factory when assigned the number 10. Upon seeing any fuse at the front which was stamped No.10, artillerymen viewed them with suspicion and would no longer use them. To resolve this matter the Ministry of Munitions renamed the factory No. 21 and investigated and resolved any manufacturing defects so White & Poppe produced fuses could once again be used normally.

Perhaps the most important development involved Daimler reaching agreement with the War Office (on the 21st April 1915) for them to lease part of the company's Radford Estate to erect an aerodrome there. This officially became termed the Aircraft Acceptance Park No.1 [I] and, with eventually nine hangars, was laid out alongside the firm's Radford factory[137].

5.7 Ownership and Control

Due to the greater level of government intervention (outlined in section 5.5), many engineering factories became controlled by the Ministry of Munitions during the mid-war period. The first such works in Coventry included the Ordnance Works and Alfred Herbert Ltd., both in July 1915, highlighting their national significance. By the end of the year the number had increased 48 "controlled establishment" factories within the mid-war cluster. No longer were their business decisions (such as production schedules or investment decisions) taken solely by Chairman or Boards of Directors. Everything a firm wished to do had to be in line with Ministerial "controlled establishment" regulations and if expansion or recruitment was desired, approval had to be granted. To enforce this control, often these firms had on-site inspectors sometimes in the form of a military officer. For example, White & Poppe had an invalided Captain present at their works to monitor if "controlled establishment" procedures were being adhered to[138].

The impact of greater governmental control upon and within the cluster was no longer firms could carry on as 'business as usual': complete industrial mobilisation was called for and instigated. Also no longer was it left to the War Office to use market forces (price inducement), or left to individual entrepreneurs and firms (noticing potentially lucrative contracts), to organise efficient national munitions supply as had been the case during 1914.

[137] Frost (1920), Long (1995) p102 & p105 and Smith (2004) p14.
[138] *The Limit*

To carry through this change locally, a local committee - the Coventry Armaments Output Committee (C.A.O.C.) [M] was established, largely through the willingness of the city's business community to help meet the needs for huge quantities of shells and fuses[139]. In essence, the city and the outlying districts became a form of industrial co-operative where all firms which could participate in armaments and munitions production were invited to tender for orders[140]. The first order which the C.A.O.C. tendered for and secured was to produce 100,000 18pdr. High Explosive (H.E.) shells at initially 10,000 per week for 18 shillings each[141]. The C.A.O.C would then, dependent upon firm size and capability, subdivide the contract between various firms and provide them with technical, financial and administrative support. For this they charged 2 shillings per shell for their management fees, leaving 16 shillings per shell for the firms. Contracts could still be obtained by Coventry firms negotiating directly with the M.O.M., but the smaller firms especially were now being organised and managed exclusively through the C.A.O.C.[142].

A letter from David Lloyd George, then Minister of Munitions, to the Coventry Mayor, Malcolm K. Pridmore (reproduced overleaf), is testimony to the importance attached to the C.A.O.C's ability to meet munitions supply at this critical stage of the war. With this committee now in operation, and many of the leading engineering firms now setup as "controlled establishments" the city's latent capacity for armaments and munitions production was becoming fully mobilised.

[139] See the following chapter for the composition of the C.A.O.C. and NA MUN5/363/1121.24/2, MUN5/363/1121.24/4 and H.M.S.O (1920) *History of the Ministry of Munitions* Chapter X, Pt.II p101-103 for further details.
[140] The complete area covered by the C.A.O.C. included Coventry, the Foleshill District (which at this time was partly within and outside the city boundary) and the two small villages of Berkswell and Wolston which were five miles from the city. NA MUN5/363/1121.24/4 p3.
[141] H.M.S.O (1920) *The Official History of the Ministry of Munitions,* Appendix III p146, Chapter X Pt.II *General Organisation, Midlands* p102 and *Industrial Mobilisation 1914-1915*: Chapter III Pt III *Local Organisation* 31st March - 28th April, p70 and C.H. 11th /12th June 1915.
[142] NA MUN5/363/1121.24/2 and NA MUN5/363/1121.24/4

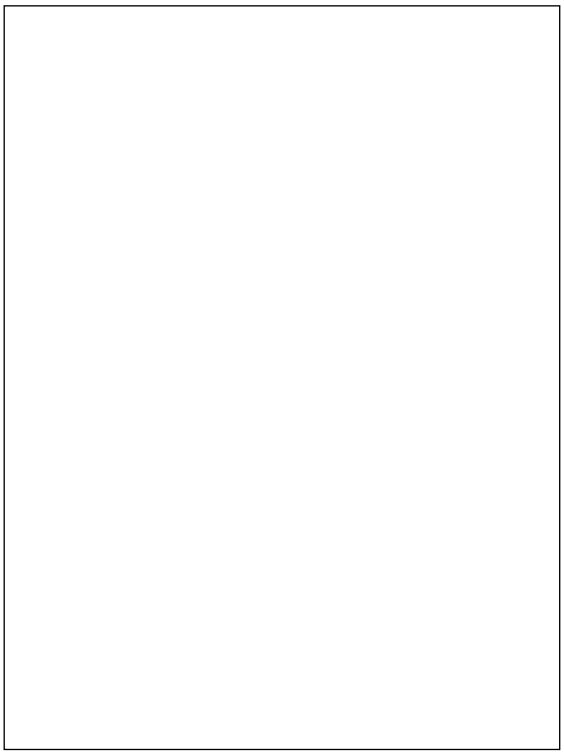
Figure 16: Letter from David Lloyd George to the Mayor of Coventry

Source: C.H. 18th & 19th June 1915.

5.8 Armaments and Munitions Production

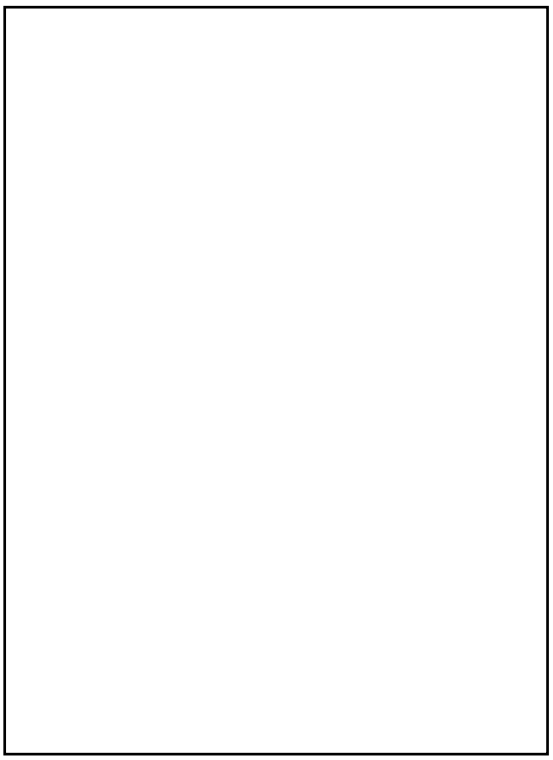
By December 1915 the number of firms now involved in specifically making shells and fuses or components thereof had increased from two in 1914 to 32 by the end of 1915. This was in direct response to the 'Shells Crisis' and the setting up the C.A.O.C. outlined earlier. Specific examples included Dunlop in their two factories [65 & 66] producing 4.5inch shell cases, Rover [122,123 &126] producing 18pdr., 4.5inch H.E. and gas shells and Standard[143] who were also now undertaking shell work. The accompanying photographs depict these High Explosive shells now being undertaken by many Coventry firms:

Figure 17: 18pdr. & 4.5-inch shells, minus their fuses, now being manufactured in Coventry



Source: *Midland Daily Telegraph* 19th July 1915

Figure 18: Complete surviving examples from the Imperial War Museum, London



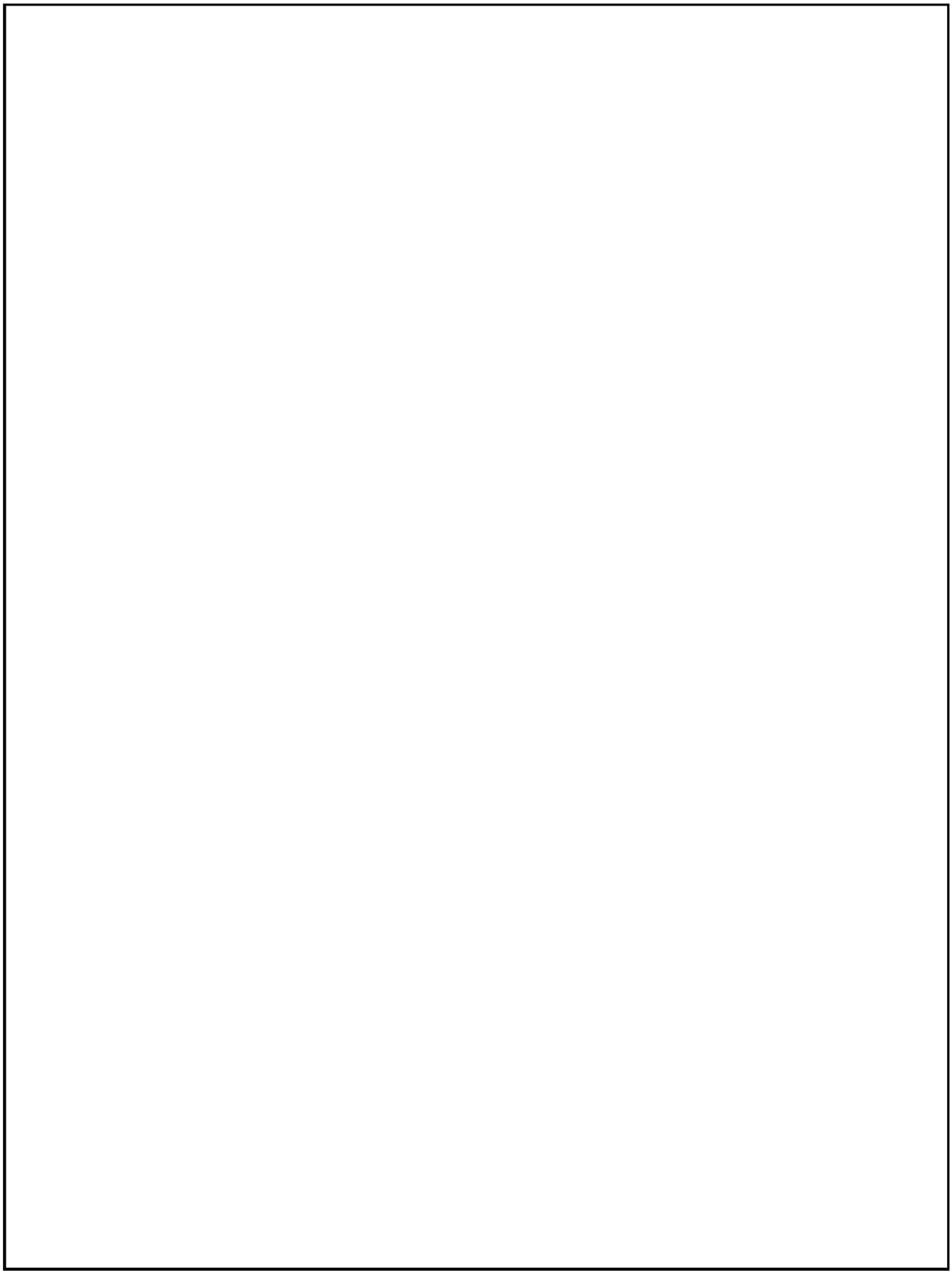
Source: Exhibits at the IWM MUN546 (18.pdr) and MUN3233 (4.5-inch)

[143] The Standard Motor Co. premises used for shell making were in the nearby town of Royal Leamington Spa where in total they leased four premises, three for shell making, and one for aeroplane wing manufacture. All four of these premises were "government controlled" in addition to their Coventry factories. This was done mainly because of the acute shortage of female labour in Coventry.

One example of the many smaller firms now undertaking such munitions work was that of the Hillman Shell Factory [81]. William Hillman, a local cycle and motorcar manufacturer, adapted one of his small vacant Auto Machinery Company premises in Lower Ford Street and with the use of female labour began to produce, along with other firms, the shells photographed in Figure 17[144]. In fact a special article was written on this particular factory in 1915 and is reproduced overleaf as it gives a good indication of the activities of such small firms by the mid-war period:

[144] C.G. 20th August 1915 and M.D.T. 14th and 17th July 1915.

Figure 19: The Hillman Shell Factory 1915



Source: *Coventry Graphic* 20th August 1915 pp4-5.

Eight of the city's machine tool factories were now also overflowing with war work as more and more machinery was needed by firms across the country taking on munitions production for the first time. Six of these were "controlled establishments" by the end of 1915[145] with their entire outputs being directed by the Machine Tool Department at the Ministry of Munitions[146] (highlighting their early national significance). Herbert's, the largest concern [76 & 77], was now supplying its renowned automatic No. 4 Capstan lathes to 'the great arsenals, ship yards, and engineering shops, not only in this country, but abroad'[147]. Smaller firms such as Walter Tatlow Ltd[148] [32], which had only been formed in 1913, were inundated with war orders for their jigs, tools and, in particular, gauges[149] and had to increase their workforce from 20 to 80. Large orders were being executed by this firm for the Royal Arsenal at Woolwich and the Small Arms Factory at Enfield as well as aircraft manufacturers and others[150].

The city's electrical engineering firms were also struggling to cope with the seemingly insatiable wartime demand for their products, particularly for high-tension magnetos. By the end of 1915 British Thompson Houston [16] (B.T.H.) were manufacturing a variety of magnetos, with their Type 'A' being made at the rate of 400 per week for use in British aircraft[151]. The firm of Morris and Lister had been forced to relocate their works in the city as their Foleshill premises [101] were inadequate for the quantities of magnetos they were now asked to produce. In 1915 they therefore reformed the business as the M-L Magneto Syndicate Ltd and relocated to a disused former mill in the central West Orchard area of the city – this they renamed their Victoria Works [103].

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[145] Albion Drop Forgings Co. Ltd.*, Brett's Patent Lifter Co. Ltd.*, Coventry Gauge & Small Tool Co. Ltd., Alfred Herbert Ltd.** (both the Butts and Edgwick factories) , Morton & Weaver, Selson Engineering Co. Ltd.* and Webster & Bennett Ltd.* (* denotes 'controlled establishments').
[146] Of which Alfred Herbert along with some of his Directors were put in charge of from April 1915.
[147] C.G. 2nd April 1915 *Automatic Allies of the Army – Romance of War-Munition Machinery.*
[148] This firm was renamed in 1916 to Coventry Gauge and Small Tool Co. Ltd.
[149] A gauge being simply an instrument used for measuring precise conformity, in this instance, usually for measuring munitions after machining. These gauges were used in ever increasing quantities within the engineering industry during the war to implement accurate repetitious production, the inter-changeability of parts, and also to assist the use of diluted labour.
[150] CG&T (1953) *Precision Par Excellence* as cited in Brittain (1989) p79-80.
[151] M.R.C. MSS.242/BT/9/11 p3.

As the war continued even this became too small:

> 'The new works of the M-L Magneto Syndicate Ltd. at Coventry…..are already running at full capacity, and are ever growing and causing continual extensions. At the present time the firm are almost exclusively employed on Government contracts'[152].

Two artist's impressions (Figures 20 and 21), highlight the size of both M-L's and B.T.H.'s factories in the mid-war cluster now both dedicated towards manufacturing high-tension magnetos:

Figure 20: The M-L Magneto Syndicate Ltd. Victoria Works, West Orchard, Coventry [103]

Sources: NA MUUN5/163/1124/25 p3. and the *Autocar* 1916

[152] *The Autocar* 1916

Figure 21: British Thompson-Houston Co. Ltd. Lower Ford Street Magneto Factory c.1916 [16]

Source: Price-Hughes (1946) p34.

Section C – Coventry's Armaments and Munitions Local Industrial Cluster January 1916 - November 1918

5.9 Historical Context

With the continuation of the war into a third and fourth year there still seemed little hope for victory. Drawn out offensives, such as the Somme in the summer of 1916 and the Third Battles of Ypres (Passchendaele) a year later, had failed to break the deadlock on the Western Front. Russia had collapsed into revolution in the winter of 1917 and sued for peace. This meant that during 1917 and 1918 Britain and France opposed a strengthened German Army across their trenches in Belgium and France as one million men were redeployed from the East Front. However, due to German unrestricted submarine warfare, political pressure, and an uncovered German plot to back Mexico in a war against them, the U.S.A. entered the war in April 1917 much to the Allies relief. That said, it would be long into 1918 before their army or their industrial strength would start to affect the allied war effort to any great extent. The onus then was on Britain and France to continue the struggle. In Coventry this attitude was expressed in terms of war posters placed around the city:

Figure 22: War Posters in Coventry c.1918, probably in Broadgate in the city centre

Source: Anon (undated) *Wartime Photograph Album*, Coventry Central Library

Success in this war of attrition would come to the nations who could effectively mobilise their full manpower and industrial might. With the Ministry of Munitions, (begun in 1915), the apparatus was in place, and gradually through 1916 and 1917 it extended its tentacles of government intervention to cover two-thirds (or possibly more) of all employed workers in Britain[153]. This was achieved through a system of controls, controllers, and 'priorities' and, to give an example, the British economic historian Sir John Clapham stated that by the end of the war common bricks appeared to be under two or three separate controls [154]. Furthermore by 1918 98 percent of all steel supply was being controlled through the apparatus of the Ministry of Munitions[155]. This then was the level of invention and control which covered all British imports, exports, industry and labour force towards the end of the war.

[153] May (1996) *An Economic and Social History of Britain 1760-1990.*
[154] Ibid, p335.
[155] *Glasgow Digital Library* (see bibliography web based sources)

To overcome the stalemate on the Western Front Britain looked to develop potentially war-winning weapons such as improved aeroplanes and aero-engines. She also looked to develop something which could breach the masses of barb-wire and the muddy trenches and was impervious to shell or machinegun fire. The tank was seen as the potential weapon to achieve this. It had been under secret development as early as 1914, but was not sufficiently developed to be used in combat until September 1916 at the Battle of Flers-Courcelette. By 1916/17 Britain fully appreciated the scale of total war. The shell and fuse supply problems had largely been resolved as sufficient quantities had been realised through the many government factories and also through greater control of industry through "controlled establishments", economic legislation and the process of labour dilution outlined earlier. These achievements were added to on the 3rd November 1916 with an order to prohibit the manufacture or assembly of motor engines, cycles and vehicles and on the 6th January 1917 by the Motor-Engines and Vehicles Order[156]. This legislation made it now impossible for firms to manufacture any kind of vehicular transport unless it was for military use or if they received a special permit to do so.

There was thus a change in emphasis for armaments and munitions production by 1917, especially for the country's engineering firms. Coventry's cycle or motor vehicle firms could no longer produce any of their peacetime products and also with a national programme of 218 shell and fuse factories now in full production these works could often produce shells and fuses more cheaply than the adapted engineering firms. In Coventry this meant the cluster had to partially adapt to producing potentially war-winning weapons such as aeroplanes, tanks and machine guns in large quantities for the remainder of the war. By 1918 these weapons were being mass-produced largely through the adoption of standardisation and the inter-changeability of parts, increasing firms' productivity and expanding their physical capacity and also by implementing a greater use of automatic machine tools with semi-skilled labour.

[156] H.M.S.O. (1920) *History of the Ministry of Munitions*, Appendix Chapter III, p32 & p58. Summaries of both Acts are reproduced in Annex 6.

5.10 Geography and Cluster Structure

Map3 (overleaf) depicts the late war cluster of armament and munition firms and the support institutions and infrastructure serving their needs by November 1918. It is further complemented with Table 10 which provides a summary of each firm, their address and the munitions[157] they were producing at this time. In addition, the key support institutions and infrastructure, serving their needs are outlined:

MAP 3 HAS BEEN REMOVED FOR COPYRIGHT REASONS

[157] If this information came to light and additionally if firm's munitions production had changed, since table 12, any new products are also listed.

Table 10: Coventry's Armaments and Munitions Cluster by November 1918

Firms

No	Firm Name	Address	Principal Trade	Wartime Work Undertaken
1	Aircraft Motor & Engineering Works	Shackletus Road (East-side 4th Property)	Engineers	Sub-contracting small aeroplane parts
2	Albion Drop Forgings Co. Ltd.	Spring Road, Foleshill	Drop Forgers	Drop Forgings for Aircraft, Aero-Engines, Automobiles & Agricultural Manufacturers
3	Arden Motor Co.	Kenilworth Road & Blacksmith's Corner	Motorcycle Manufacturers	Munitions, possibly manufacturing fuses (Unable to locate Kenilworth Road premises and Blacksmith's Corner premises are too distant to depict on this map
5	Astley, John & Sons, Ltd.	18a Butcher Row	Rope & Twine Manufacturers	Equipments for troops
6	Auto Machinery Co. Ltd.	Hood Street & Read Street	Ball Bearings and Component Manufacturer	Ball Bearings primarily for Rotary Aero Engines & Shell Driving Bands
7	Blakemore D., & Sons, Ltd	Godiva Street (North-side between 92-94)	Mudguards, wings valances; petrol tanks	Ammunition boxes for machine guns
8	Bluemel Brothers	Wolston, near Coventry	Motor & Cycle Accessories	Supplying T Friction Tubes to C.O.W.
9	Brassco, Ltd.	St. Nicholas Street, East Side	Aluminium Founders	Aluminium Magnetic Piston most likely for aero-engines
10	Brett's Patent Lifter Co. Ltd.	Foleshill Works, Spring Road	Drop Hammer Manufacturers	Patent Hammers, Power Presses, Furnaces & other installation plants together with accessories and spare parts for Motorcar Manufacturers, General Engineers, Stamping Companies, Signal Manufacturers, Locomotive & Wagon builders, Arsenals & Government factories, Ordnance & Gun Works including Dudley National Projectile Factory.
11	Brett's Stamping Co. Ltd	57 Hannall Lane	Drop Forgings	Drop Forgings in Iron, Carbon Steels & Alloy Steels of every kind and for AEC Lorries
12	Britannia Foundry Co.	32 Cox Street & Well Street	Aluminium Founders & Engineers	Delicate Aeroplane Cylinders, 15-inch Shells, Aluminium Parts for Submarines, Phosphor Bronze Gun-Carriage Bearings and numerous other castings for the Admiralty & War Office
14	British Chuck & Piston Ring Co.	Holbrook Lane, Foleshill	Chuck & Piston Ring Manufacturers	Mass Producing Piston Rings for Motor Vehicles & Aero Engines & also Piston Castings, Shackle Bolts &Gudgeon Pins.
15	British Petroleum Co.	Petrol Depot, Holyhead Road	Petroleum Manufacturers	Filling tanks with petrol for Government Motor Transports
16	British Thompson-Houston Co. Ltd.	Lower Ford Street (North-side after Hood Street)	Magneto's & Electrical Engineers	Magnetos for vehicles, aeroplanes and also Gauge Manufacture
17	Broadhurst R. & Co.	130 Queen Victoria (East-side)	Wholesale Ironmonger, Tool Dealer & Motor Accessories	Motor Lamps, Tools & Accessories
19	Burbidge, H. & Son	Victoria Works, Vecquerey Street	Wood Turners	Wooden Transit Plugs (Fuze Hole 2") for 18pdr & 4.5 H.E. Shells
20	Bushill T. & Sons Ltd.	10 & 17 Cow Lane & Little Park Street	Printers & Box Makers	Paper cartons for food supplies sent to troops.
21 & 22	Calcott Bros. Ltd.	165 Far Gosford Street & 132-134 Much Park Street	Cycle & Motorcar Manufacturers	18hp Chassis for Ambulances & some Motorcars also supplied to the Army
23	Charlesworth Bodies Ltd.	128 & 129 Much Park Street	Motor Body Builders	Rebuilt the commandeered Coventry Buses into War Department Lorries and did this also for numerous other towns Commandeered Vehicles. Also Manufacturing 100s of Ambulance Bodies, Staff Cars, Field Kitchens, Lorries for British & Allied Governments. Also built Motor Bodies for Austin cars for the Russian Government. Ambulance Bodies for Napier chassis and others.
24	Challenge Cycle & Motor Co. Ltd.	Challenge Works, 201-269 Foleshill Road	Cycle & Motorcycle Manufacturers	Unknown
25	Condor Motor & Fittings	182-184 Broad Street Garage	Engine /Aero Engine Valves	Aero Engine Valves & Aero parts since August 1914
26	Conner Magneto & Ignition Ltd.	Copeswood Grange, Stoke	Magnetos & Electrical Engineering	Magnetos
27	Coundon Small Arms Ammunition (SAA) Factory (formerly Buckingham's Engineering)	Dover Street & Farmers Yard, Spon Street	Sidecars, cars & Engineers	Incendiary Bullets for use in Machine Guns primarily for aircraft to defeat the Zeppelin menace
28	Coventry Acme Motor Co. Ltd.	Osborn Road, Earlsdon	Motor Body Builders & Rex Motorcycles	Stokes Trench Mortars
29	Coventry Aluminium & Refining Co. Ltd.	Nelson Street	Aluminium Founders	Castings in Gun Metal, Phosphor Bronze, Aluminium, & Brass etc
30	Coventry Aviation Co. Ltd.	34a Earl Street	Manufacturers of Metal Parts for Aircraft	Hinge Pins, Nuts, Washers, Wire Ferrules, Pins, Fork Ends, Metal Thread Screws, Wood Screws for Aircraft
31	Coventry Chain Co. Ltd.	Chain Works, Spon End	Transmission Chains & Accessories	4 Different Types of Chains used in Tanks, 18pdr & 2.75-inch Shells for the Coventry Armaments Output Committee & 1000s of Fuses & Wooden Transit Plugs (Fuse hole 2-inch) No.3 mk.II From October 1915
32	Coventry Gauge & Small Tool Co. Ltd.	Warwick Street, Earlsdon	Gauge & Machine Tool Makers	Gauges & Machine Tools
33 & 34	Coventry Eagle Cycle & Motor Co. Ltd	4 Lincoln Street & 201-269 Foleshill Road	Bicycles & Motorcycles	Unknown
35	Coventry Engineering & Pattern Co. Ltd.	Godiva Street (North-side after bridge)	Pattern Makers	Patterns for all kinds of Motor & Aircraft
36	Coventry Magneto Co. Ltd.	15a Union Street & Fleetwood Works, Greyfriars Lane	Magnetos est. 1914	Magnetos, including repairing
37 & 38	Coventry Metal & Iron Co. Ltd.	Meadow Street & 8 Trafalgar Street	Metal Manufacturers	Unknown
39	Coventry Motor Fittings Co.	104-105 Far Gosford Street & Croft Road	Motor Accessories Manufacturers	Cast Aluminium Radiators for Heavy War Transport Vehicles
40	Coventry Motor Foundry Co.	Road Street, (North-side)	Manufacturers of Motor Castings	Unknown
41	Coventry Motor & Sundries Co. Ltd.	34 Spon End (South-side before railway arches)	Motor Body & Motor Hood & Screw Manufacturers	Unknown
42	Coventry Movement Co., Ltd.	Spon Street (South-side)	Watch Movements (supplied W & P in Boer War)	Delicate Aeroplane Parts, Motor Switches, Taps, Petrol & Oil Indicators, Grease Cups, Nuts & Bolts & other components
43	Coventry Munitions Ltd.	Gosford Street (South-side next to Hotchkiss)	Munitions, only seem to be in existence 1916-18	Shells & fuses, possibly filling
44 - 46	Coventry Ordnance Works Ltd.	Ordnance Works, 11 Ordnance Road	Armaments & Small Tool Manufactures	Filling empty primers manufactured through the C.A.O.C. & directly for the M.O.M. Howitzers, Naval Guns, Shells & Fuses, Fuse Heads & armour plate for Tanks. R.A.F. R.E.8 & Sopwith Snipe Aeroplanes. 130H.P. Clerget Cylinders under Contract 87/E/1039, Aeroplane Undercarriages of the "V" type, Metal Fittings for main & body struts and wheels for Sopwith Snipes. Also supplying Swarf Metal to Rudge Whitworth.
47	Coventry Packing Case Co.	Holyhead Road (North-side)	Carriers & Packing Case Manufacturers	Tin lined Packing Cases
48	Coventry Plating & Presswork Co. Ltd.	Lower Ford Street	Platers, Polishers & Presswockers	Most likely undertaking the Presswork, plating & polishing for Radiators for Army vehicles for Coventry Radiators
49 & 50	Coventry Premier Ltd.	10 Read Street, Hillfields & 8 Lincoln Street	Cycles, Motorcycles & Motorcar Manufacturers	Motorcycles to Russia, 2.75 High Explosive Shells for the Coventry Armaments Output Committee between February 1916 and 1917 and also 600 Hotchkiss machine gun cradles and deflectors between 1917 and 1918.
51	Coventry Radiator Co. Ltd	Raglan Works, Raglan Street	Motor Vehicle Radiators	Making heavy type Radiators for Army vehicles
52	Coventry Repetition Co. Ltd.	Raglan Works, Canterbury Street	Component Manufacturer	Turnbuckles, pins, stream line wires, fork ends, eye bolts, Universal joints & propeller bolts. Small screws, studs, nuts, washers, special bolts, including the many important parts of an engine, such as connecting-rod bolts.
53 & 165	Coventry Simplex Engines, Ltd. (renamed Coventry Climax 1917 onwards)	Payne's Lane Works	Engine Manufacturers	100s of Simplex Engines used for generating sets to operate Searchlights & Admiralty War Contracts so ceased making commercial engines by 1915
54	Coventry Stamping Co. Ltd.	Holbrook Lane, Foleshill	Drop Forgers	Head Forgings for 6-inch & 60-pdr High Explosive Shells from June 1916 onwards. Base Plate Stampings for 6-inch High Explosive Shells from July 1916 onwards. Suppliers to Armstrong Whitworth, Triumph, Arrol-Johnston, Crossley Motors, Coventry Ordnance and others.
55	Coventry Swaging Co. Ltd.	White Friars Mills (Needle), Whitefriars Lane	Spokes, Nipples & Sewing Machine Needles	Unknown
56	Cramp Engineering Co. Ltd.	12 Union Street	Ball Bearing Grinders & Polishing Lathes	Machining, Castings, Forgings & Stampings
57 & 58	Crouch Motors Ltd.	34 Bishop Street & Tower Gate Works, Cook Street	Motorcar Manufacturers	Military contracts'
59	C.W. Walker	Progress Works, 123 Allesley Old Road	Toolmaker & Engineer	Small tools, gauges and jigs.
60 & 61	Daimler Co. Ltd.	Motor Mills, Sandy Lane & Radford Works	Motorcar, Commercial Vehicle & Engines	Cars & Lorries of all types for Military use. Aeroplanes including R.A.F. R.E.8 & Airco Ameins III, Aero-engines R.A.F.4a/d. Tank Engines & Gearboxes, 12" Shells, Bentley BR2 Rotary Aero-engines
62	Dingley Brothers	Viaduct Works, 74 Spon End	Cycle & Motorcycle Manufacturers	Hotchkiss machine gun cradles and deflectors
63	Doherty Motor Components Ltd.	Palace Yard, Earl Street	Sheet Metal Workers & Component Manufacturers	Unknown
64	Duggins Ltd.	Henry Street (South-side)	Malleable iron founders	Malleable Iron Castings for
65	Dunlop Rim and Wheel Co. Ltd.	Alma Street North-side	Wheel & Rim Makers	Starter Units for Rolls Royce Eagle Aero-engines & Cylinders for Gnome Rhone Mono Solpape Aero-engines.Tyres & Rims for British Army Vehicles & 4.5 H.E. Shells for the C.A.O.C
66	Dunlop Rubber Co. Ltd.	Alma Street, (South-side)	Motor Accessories Manufacturers	Specialist Types of Tyres & Rims for Aircraft and military vehicles
67	Engineering Accessories Co. Ltd.	2 Hill Street	Aeroplane Fittings Manufacturers	Motor Car Valves, Pistons,
68	Excel Radiator & Sheet Metal Co.	133 Foleshill Road, Foleshill	Sheet Metal Workers	Sheet Metal in Copper, Brass,
69	Farmer & Son	116 Queen Victoria Road (Right-hand, East-side)	Engineers & later Press Tools & Pressings	18-pounder H.E. shells for C.A.O.C & Laminations for Magnetos
70	Fowler & Smith	Coventry Copper Works, 44 (back of) Bayley Lane	General Coppersmiths	Brazing on Empennages, Elevators, Fins, Rudders for Aeroplanes. Brackets, Steering Rods and other parts for Motor Lorries
71	Geo. Taylor & Sons	Payne's Lane (West-side)	Engineers & Machine Tool Makers	Air & Oil Pumps for Aeroplanes
72	George Wilson Gas Meters, Ltd	Foleshill Road, Foleshill	Gas Meters, Thermal Heaters, Gas Stoves & Accessory Manufacturers	Non-ferrous castings in aluminium & gun-metal specialised in and made for motor, aeroplane engines, gun fittings, shell parts & mines
73	Globe Foundry (Coventry) Ltd.	Leicester Place, Leicester Street	Iron founders	Unknown
74	Gloria Cycle Co. Ltd.	Between 12-13 Much Park Street	Cycle & Sidecar Manufacturers	Supplying Sidecars for Triumphs & also supplied for the War Dept. Gloria Pigeon carrying Sidecars for use in communications
75	Guest James J. & Co.	The Charterhouse Works, Northfield Road	Engineers & Machine Tools	Grinding Machines
76 & 77	Herbert Alfred Ltd.	St. Thomas Villas, The Butts & Edgwick Works, Canal Road, Foleshill	Machine Tool Makers & Iron founders	Machine Tools of all types, but predominantly the No.4 Capstan Lathe
78	Hazlewoods Ltd.	Albion Mills, 52 West Orchard	Motorcycle & Combination Manufacturers	Combination Motorcycles and sidecars mainly for military forces in British Colonies
79	Hill, Rowland & Sons Ltd.	Albion Foundry, King Street	Aluminium & Gunmetal Founders & Pattern Makers	Aluminium Castings for mainly Aero Pistons, but also for Submarines, Airships, Ambulances & Transport Vehicles
80	Hillman Motor Co. Ltd.	Humber Road	Motorcar Manufacturers	Unknown
81	Hillman Shell Factory	Lower Ford Street	Shell Producers	High Explosive Shell Cases.
82	Holley Bros	147 Holyhead Road	Carburettor Manufacturers	From 1917- produced Carburettors for M.O.M. Vapourizers & Shell Sockets & Zenneth Carburettors for Sidderley-Deasy's Puma engines
83 - 85	Hotchkiss et Cie	Artillery Works, Gosford Street	Machine Gun Manufacturers	Machine Guns in Tanks, Cavalry Aircraft, AA-Guns & Trench Warfare for the Admiralty, War Office, Air Board & M.O.M & also supplied Machine Guns to Allied Countries
86	Humber Ltd.	Humber Works, Stoke	Cars, Motorcycles, Engine Manufacturers	4.5" H.E. Artillery Shells, French Mortar Bombs, Field Kitchens, Artillery Draught Poles, Aeroplanes in the form of the Avro 504a/k Bentley Rotary Aero Engines BR1 & BR2. Also 100s of 'wicked-looking steel darts for throwing from aircraft'.
87	I.F. Forester	"Halvetia", Albany Road (South-side)	Watchmakers	Chronometers for the Admiralty
88	Kalker, E. & Co.	23 Much Park Street (East-side)	Wire & Electric Cable Manufacturers	Shells from mid 1915 likely for the C.A.O.C., No. IIA Special Magneto cables and Armoured Electric Lighting and High & Low Tension Ignition Cables For Automobiles & Aircraft
89	Lawton Tube Co.	London Road Mills, London Road	Makers of Solid Drawn Tubes	Brass & Copper Tubes for Motor Cars & Aeroplanes
90	Lea Francis Ltd.	Between 9-10 Lower Ford Street & Much Park Street	Cycle, Cars & Motorcycles Manufacturers	Range-Finding Gear & Sundry Instrument Manufacture for the Admiralty
91	Lee F. & Co.	7 Dover Street, East side 1st & 2nd properties	Watch & Electrical Jewel Manufacturers	Jewels for torpedoes, ships compasses & electrical meters
92	Martino's Treating & Testing Works (Spring 1916 onwards)	Sandy Lane Right hand East-side after bridge	Testing Laboratories	Annealing, Case-hardening & Heat-Treatment of Steels; Mechanical Testing & Chemical Analysis of all materials in Aircraft & Engineering Construction
93 & 94	Matthews, Henley & Watson Ltd.	Hales Street (Showroom), & Lion Foundry, 117 Cross Cheaping, both West Orchard	Engineers, Builders, Castings & Constructional Steelwork	Cywch cartridges & guns
95	Maudslay Motor Co. Ltd.	Parkside & Quinton Road	Cars & Commercial Vehicles	Type 'A' Subsidy Lorries for the War Office, Post Office, The Great Western, Great Eastern, Midland & Great North of Scotland Railway Companies, Lever Bros. and others & Aero Engine Components
96	Middlemore & Lamplugh Ltd	87-89 Little Park Street	Cycle Saddle & Mudguard Manufacturers	Supplying Leather items to War Office & Admiralty & Foreign Governments
97 & 98	Mills-Fulford Ltd.	Crown Works, Stoney Stanton Road & Progress Works, 287 Stoney Stanton Road	Cycle & Sidecar Manufacturers	Supplying Sidecars for Officer Transport for the R.F.C. & also 'Armaments'
99	Monk Engineering Co. Ltd.	213 High Street South-side between Banks	Engine Makers & Experimental Engineers	Motorcar & Aeroplane Engines, Gear Boxes and Rear Axles, Steering Gear, Diesel Engine Parts, Control Clocks, Gun Sighting Gear and Firing Mechanisms.
100	Montgomery Sidecars	Between 9-11 Lower Ford Street	Sidecar Manufacturers	Sidecars for the Military & Triumph
102	Morton & Weaver	137 & 139 The Gear Works, Cox Street	Engineers and Machine Tool Makers, and Early Aeroplane Manufacturers	Gauges, machine tools, small tools and gear cutting for the Allies Victor Engines as auxiliaries in aeroplanes and bombing sights for aircraft
103	ML Magneto Syndicate, Ltd. (formerly Morris & Lister)	Victoria Works, West Orchard	Magneto Manufacturers	Magnetos for Vehicles & Aeroplanes
104	Omega Cycle Works	Croft Road (North side 2nd property along)	Cycles & Motorcycles	Hotchkiss machine gun bodies
105	Parc Ltd.	Lockhurst Lane & Branch Works in Earlsdon	Tool Makers & Engineers	Jigs, Gauges, Milling Cutters, Reamers, & Tools for Capstan Lathes. For Automatics Box Tools, Knee Tools etc.
106 & 107	Pass, Thomas Ltd.	48 West Orchard & 101-102 Little Park Street	Motor Body Builders	Government Transport Wagons, 5 Ton Self Contained Trailers, Ambulances & Service Cars. Also Bodies for Maudslay Motor Lorries
108	Phoenix Castings Ltd.	Phoenix Foundry, Grove Street from April 1915	Aircraft, Motorcar & General Engineering Castings	Unknown
109 & 110	Pistons Ltd.	Far Gosford Street (North-side 1st property) & Far Gosford Street (South-side after Bramble Street)	Pistons & Gudgeon Pins	Making same for Aeroplanes, Motor Lorries, Motorcars & Motorcycles in Iron, Steel or Aluminium
111	Priory Accessories (Spencer Bros from 1918 onwards)	Priory Mill, Priory Street	Reed, Slay, Harness & Motor Accessories Manufacturer	Heavy-pattern steel slays for military web equipment
112 & 113	Randle Radiator Co.	Nelson Street (1914) & Mile Lane, Cheylesmore	Radiator Manufacturers	Radiators for Maudslay's Lorries, all other Motor Vehicles, for Agricultural Tractors, Stationary Engines, Electric Lighting Sets & Aeroplanes
114	Reliance (Coventry) Ltd.	Nelson Foundry, Trafalgar Street	Sheet Metal Workers	Unknown
115	Rex Motor Manufacturing Co. Ltd.	Earlsdon Works, Osbourne Road	Car & Motorcycle Manufacturers	Stokes Trench Mortars & Turning Bomb Tubes
116 - 118	Riley Motor Co. Ltd	City Works, St. Nicholas Street & Cunard Works, Aldbourne Road	Motorcycle & Motorcar Manufacturers	Gauges, Wire wheels for Daimler, Vauxhall, Crossley staff cars and others Aero Engines & Components inc Pistons, Riley Engines for Generators. £15,000 contract for Riley Aero Engines, £17,000 contract from Vickers & Government contracts for shells & fuse heads & Ambulance Stretch Carriages Gaines & Adapters No.4 mk.I 30th October 1916-1917
119	Nero Engine Co. (Subsidiary of Riley Motor Co.)	Durbar Avenue, Foleshill	Aero Engines & Aero Engine Components	Unknown
120 & 121	Rotherham and Sons Ltd.	Gosford Street Works, Bayley Lane & 27 Spon Street (South-side)	Watch Manufacturers, Engineers & Motor Components	Supplying T Friction Tubes to C.O.W. Rifle Clips for cycles, Motor taps, Aeroplane parts, Mechanical Clockwork fuses, delicate fuse work for Singers, scientific instruments & their components
122 - 126	Rover Co. Ltd. & Rover Cycle Co. Ltd.	New Meteor Works, Rover Road. Helen Street, Foleshill. Fleet Works & St. John's Works, & Foundry at 42 Spon Street	Motorcycles, Motorcar & Cycle Manufacturers	Maudslay Lorries & Sunbeam Staff Cars, Stokes Trench Mortars, Gas Shells, Fuses and Tank Transmissions. Bicycles for the War Office & Post Office. 18pdr Shells 4.5-inch H.E. & S.K. Lachrymatory Shells Also manufacturing Aircraft Parts from 1916 onwards including Gnome Aero-engine Piston Castings
127 & 128	Rudge-Whitworth Ltd.	Rudge Works, Crow Lane, 34 Spon Street & 36 Hertford Street	Cycle & Motorcycle Manufacturers	Fuses, Rifle Bullets, Sidecars to the Belgian Army, Fuse caps, Sidecar Bodies for Italy to use as mountain lifts to supply troops. Aerial Torpedoes of various sizes and capacities from 500lbs to 50lbs. Floating Mines for use at sea, Artillery shells, and Machine-gun shields. Barbed Wire Cutters, Carburettors in aluminium most likely for aeroplanes. Water Pumps, Landing Gear and any metal fittings for the B.E.2 aeroplane. Detachable Wire Wheels for use in Crossley Ambulances, Staff Cars and Aeroplanes
129	S. Alexander & Sons	61 Allesley Old Road	Wholesale Watch Manufacturers	Watches for the Admiralty, War Office & Royal Aircraft Factory
130	Samuel Yeomans	48a Spon Street (South-side Court 14)	Watchmakers	Making Steel Hammers for Fuze No.106
131	Selson Engineering Co. Ltd.	St George's Road	Machine Tools & Engineers	Shaping & Radial Drilling Machine Tools
132	Sherbourne Plating Co.	143 Lower Ford Street	Platers & Polishers	Chromium, Nickel, Silver, Copper, Brass & Tin Plating. Polishing, Enamelling Silver & Copper Oxidizers. Bronzing & Lacquering
133 & 134	Siddeley-Deasy Motor Co. Ltd.	51 Parkside & 128 Much Park Street (Experimental aeroplane design work at Charlesworth Bodies)	Motorcar & Engine Manufacturers	R.E.8 & Airco Ameins III Aeroplanes & Puma Aero Engines & over 1,000 propellers manufactured. Stonelegh Lorries, Field Kitchens & Siddeley-Deasy 18hp Ambulances & Cars for the War Office
135	Singer Motor Co. Ltd.	50-54 Canterbury Street, Hillfields	Motorcycle, Cycle & Motorcar Manufacturers	Hispano-Suiza Aero-engines & 10,000s Fuses No.80 & 131.
136 & 137	Smith's (Thomas) Stamping Works Ltd.	Red Lane Works, Red Lane & Aircraft Works, Ribble Road & Gosford Green	Drop Forgers	1,500 Components for the Associated Equipment Company's 5ton Lorries. Paravanes for Minesweeping for the Admiralty. Forgings for the Aeronautical Dept. & Admiralty Air Dept. also.
138 - 142	Standard Motor Co. Ltd.	Cash's Lane Works, Bishopgate Green Works, Widdrington Road Works & Canley, near Coventry	Cycles & Motorcar Manufacturers	18pdr High Explosive Shells for the Coventry Armaments Output Committee and Fuses. Sopwith Pup, R.A.F. R.E.8 & Bristol F2b Aeroplanes
143	Star Foundry (Hadley A.E.)	121 Cox Street (West-side)	Aluminium, Gun Metal, Bronze & Phosphor Founders	'Many important Government Contracts have been carried through, and at present their energies are concentrated on War Work"
144	Sterling Metals Ltd.	Northey Road, Foleshill & 1 George Street	Iron Founders	Castings for Army Vehicles & Aeroplanes and also castings and Swarf for Fuse 103 for the Rudge Whitworth Company
145 & 146	Swift Cycle Co. Ltd.	Cheylesmore Works, Cheylesmore Street & Quinton Works, Quinton Road	Cycle, Motorcar, Motorcycle Manufacturers & Motorbody builders	18pdr. & 4.5-inch High Explosive Shells for Coventry Armaments Output Committee, Pipe Boxes, Flanges & Fuselages for Vickers bombers & Hispano-Suiza Aero-engines. 1,750 Hotchkiss Machines Filling Ammunition Feed Strips or Belts between 1917 and 1918
147	Tooby, Adkins & Co.	41-42 Bishop Street	Leather Factors for the Motor Trade	Leather equipments for troops
148 & 149	Triumph Cycle Co. Ltd.	Triumph Works, Priory Street, Much Park Street & Dale Street	Cycle & Motorcycle Manufacturers	Gauges & 30,000 Motorcycles for the British Army 2 ½ inch Fuse-Heads and Primers & 2 ½ inch large Shell Noses Friction T. Tubes MK.IV From August 1915
150	Turner, W.E. & Co. (1916-)	Bridge Works, 151-152 Far Gosford Street	Engineers, Machinists & Machine Tool Makers	Experimental Engine work & Jigs, Tools, Gauges & Machine Tools
151 & 166	Valves, Ltd.	Jordan Well	Valves, Guides & Inserts for Engines Manufacturers	Manufacturing Valves, Guides & Inserts for Engines for the Admiralty & the War Office
152	Van Raden & Co. Ltd.	567 Foleshill Road	Motor Ignition & Electrical Storage Battery Manufacturers	Coil, Accumulators & Batteries for the Post Office, Admiralty, War Office & Colonies
153	Vulcan Patternmaking Co. Ltd. (1917-)	Carlton Works, Much Park Street	Pattern Makers	Motor & Aero Patterns. Also Jigs, Machine Tools & Patterns for all the Engineering Trades. Castings in all Metals
154	Ward, E. J.	Smithy, Spon End.	Blacksmiths	Producing 1000s of horse shoes for the Army
155	Waygood Otis Ltd. (Clarke & Mote from 1916 onwards)	Vulcan Iron Works, Well Street	Aluminium Founders	Unknown
156	Webster & Bennett Ltd.	Northey Road Works, Foleshill	Machine Tool Makers	Duplex Milling and Boring Machines and Lathes and also Cutting-Out Tables for Aeroplane work
157 & 158	W. Edwards and Sons	Victoria Works, Gulson Road (Shut-lane Mill South-side) & Day's Lane (South-side)	Paint-Mill Manufacturers & General Engineers	Machine Tool Firm supplying railway companies, motor and paint manufacturers.
159	White, Joseph & Sons	58a Earlsdon Street	Engineers, Machinists & Watch Chronometer Manufacturers	Wooden Transit Plugs (3 five hole) for 18pdr & 4.5-inch High Explosive Shells
160 & 161	White & Poppe Ltd.	Lockhurst Lane, Foleshill & National Fuse & Filling Factory No.10/21, Holbrooks Lane	Engine Builders & Motor Engineers	Fuze 80 Bodies, 18pdr. Shell Sockets, rings, caps and base plugs. Subsidy Engines for Lorries. Fuze 100. Fuses, Gaines & Detonators. Manufacturing Wings and top and bottom Aerofoils for Aeroplanes. Also supplying Swarf Metal to Rudge Whitworth.
162	W.H. Jones & Sons Ltd.,	Holbrooks Lane	Building Contractors	Erected many building extensions for local munitions firms & 1000s of Ammunition Boxes & also laminations for magnetos
163	Williamsons, A. & Co. Ltd.	77 Moor Street	Engineers	Armaments & War Equipment
164	Williamsons, H. & Co. Ltd.	Errington Watch Factory, Lower Holyhead Road	Watchmakers	Large contract for Wrist Watches for Military Officers & Pocket Watches for other ranks
165	Coventry Climax Engines Ltd.	East Street Works	Engine Manufacturers	100s of Simplex Engines used for generating sets to operate Searchlights & Admiralty War Contracts so ceased making commercial engines by 1915
166	Valves, Ltd.	133 Foleshill Road, Foleshill	Valves, Guides & Inserts for Engines Manufacturers	Manufacturing Valves, Guides & Inserts for Engines for the Admiralty & the War Office

Support Institutions and Infrastructure

Letter	Support Institutions and/or Infrastructure	Address	Type of Institution or Infrasture
A	Ministry of Munitions	14 Much Park Street (East-side)	Local Coventry office for the Ministry of Munitions
B	Aircraft Inspectorate Department	44 Bayley Lane	Local Aero-engine and Aeroplane Inspection Office
C	Cycle and Motor Cycle Manufacturers & Trader's Union Ltd	The Towers, Warwick Road	Pre-war Business Support Institution
D	Labour Exchange	Lower Ford Street	Pre-war Labour Recruitment Infrastructure
E	Drill Hall	Queen Victoria Road	Resident Battalions Army Hall
F	Munition Works Bureau	St Mary's Hall, Bayley Lane	War-time office for Munition Worker Recruitment
G	Munitions Inspection Dept. Office	10 Ordnance Road	Local Munitions Inspection Office
H	Coventry Chambers of Commerce	9 Masonic Buildings, Little Park Street	Pre-war Business Support Institution
I	Radford Aerodrome Aircraft Acceptance Park No.1	Next to Daimler's Radford Factory	Aerodrome and proving ground for city's Aeroplanes
J	Whitley Abbey Aerodrome	South of Whitley Common	Aerodrome used for storage purposes for the R.F.C.
K	Drapers Club	Drapers Hall, Bayley Lane	Established Private Social Club
L	Coventry & County Club	Queen's Road	Established Private Social Club
M	Coventry Armaments Output Committee	The Towers, Warwick Road	Local Co-operative Munitions Committee

The Complete Late-War Armaments and Munitions Cluster **150 Firms and Support Institutions or Infrastructure**

Cycle, Motorcycle & Motorcar Manufacturers New Entrants = 4, Total = 34,	Component Manufacturers New Entrants = 14, Total = 50	Machine Tool Manufacturers New Entrants = 8, Total = 16
Armament Manufacturers New Entrants = 2, Total = 5	Metal Working Firms New Entrants = 21, Total = 32	Support Institutions and Infrastructure New Entrants = 5, Total = 10

Sources: See bibliography

By November 1918 as many as 137 armament and munition works were operating within an expanded cluster covering an area of around 13sq.miles. This represents a growth of 49 firms or around a 40 percent increase when compared to the mid-war cluster. This shows that the major growth period of the cluster was in the mid-war period with the initiation of the Ministry of Munitions. Out of the total of 137 firms forming the late-war cluster, 61 percent were cycle, motorcycle and motorcar assemblers and their component suppliers. This was a continuance of the early and mid-war firm typology and demonstrates how the city's core sector continually formed the nucleus of armaments and munitions firms within the cluster. Despite this, proportionally the number of late-war new entrants that originated as cycle, motorcycle and motorcar firms had declined when compared to the mid-war period. Therefore new entrants into the cluster were increasingly from other engineering sectors. Following and increasing upon the mid-war pattern, these emerged mainly from the metal working sector, which between the mid and later-war cluster, had almost trebled from 11 to 32 firms involved in munitions.

Some of these metal working new entrants were small firms such as Fowler & Smith [70] who described their activities as: 'brazing is continually being executed for Aeroplane parts, including Empennages, Elevators, Fins and Rudders etc. [and] also Brackets, Steering Rods and other parts for Motor Lorries'[158]. Due to firms of this nature only requiring modest premises they were still able to find vacant premises in the city's core. Other larger new entrant metal working businesses were forced to locate outside the city's boundary such as the Coventry Stamping Company Ltd. [54] to the north of the city. It was noted earlier how firms such as ML Magneto [103] and Hotchkiss et Cie. [83, 84 & 85], during the mid-war period, could still acquire vacant premises in the city's core to expand their manufacturing capacity. It would appear by the late-war period the available stock of vacant factories in the city's core had been utilised and firms now had to look elsewhere in order to expand. This pattern can be observed for both a new entrant and an established firm within the cluster.

[158] *Coventry and its Industries Official Handbook* 1918 pp79-80

The Standard Motor Company had been operating from a collection of scattered small and medium sized premises in the northern Foleshill district of the city [138, 138, 140 & 141]. Upon receiving large aeroplane contracts they were forced to relocate their main activities to a new purpose built works outside the city boundary. For this they chose to erect a large new factory at Canley, South West of the city, which proved ideal for aeroplane manufacture with the firm's wartime output reaching nearly 1,600 aeroplanes in only 2 years [142]. Figure 23 depicts some of this production:

Figure 23: Sopwith Pup Aeroplanes under construction at Standard's Canley Works 1916-1918 [142]

Source: Davy (1967) *The 'Standard' Car 1903-1963*

Similar to the relocation of Standard, during 1916, the Manchester firm of Peel Conner wished to establish a large new factory in Coventry. They chose land to the East of the city in the area of Stoke for the magneto factory of Conner Magneto & Ignition Ltd. [26]. These two examples highlight how the cluster was becoming constrained within the existing city limits and new entrants had to continually locate outside the existing city boundary, especially if large modern premises were desired.

Areas devoid of any munition firms included land near to the central railway station, just South East of Alfred Herberts [76] factory. Furthermore only works such Daimler's Radford premises [61] the National Fuse & Filling Factory No.10/21 [161] and the Ordnance Works [44, 45 & 46] had a direct link to the city's rail network to despatch their completed munitions. This suggests that many of the firm's outputs would have been packed and despatched to be stored within the large marshalling yards around the main rail station and that is why no firms where located in that area. Another reason was because the late-war cluster was now served by two aerodromes. Radford Aerodrome [I] was where the city's completed aeroplanes departed between 1915 and 1918. These would leave the factories by road (such as Siddeley-Deasy's Parkside or Standard's Canley works), with their wings detached, and then final assembly, testing and flying being conducted there. Towards the end of the war this was added to with Whitley Aerodrome [J] for the Royal Flying Corp. There is no evidence flying occurred there during the war and it was merely used for storage purposes. This suggests that it could have provided additional flying capacity for the city if the war had continued on into 1919.

Between 1916 and 1918 further support institutions were setup within the cluster in order to cope with the vast quantities of munitions the city was producing. These included offices for the Aircraft Inspectorate Department (A.I.D.) [B] and Munitions Inspection Department [G]. These were necessary to offer inspection, for any armaments and munitions produced, particularly for the smaller factories as most of the larger firms had their own on-site inspection capabilities or where strict quality standards need to be adhered to e.g. aero-engines.

5.11 Ownership and Control

The Coventry Armaments and Output Committee (C.A.O.C) continued to co-ordinate munitions supply within the late-war cluster, however its role had evolved. It was noted in section 5.7 that it was tendering directly to the Ministry of Munitions (M.O.M.) for contracts which, if accepted, could then be dispersed throughout the cluster along co-operative lines.

By 1916 onwards, this situation had reversed and it was now the Ministry itself who instructed the Committee to place contracts with firms. Furthermore the Committee's official history acknowledges how they found it increasingly more difficult to co-ordinate the city and especially the larger firms who preferred to deal outside of their control[159].

Alongside the Armaments Committee, other important committees were established within the late-war cluster to serve the needs of munition firms. One such body was the Coventry Local Advisory Committee instigated by the Ministry of Labour, and tasked with particularly looking after welfare issues for the many women now working in the city's munitions factories[160]. Another was the Coventry Local Munitions Tribunal which operated between 1915 and 1918. This was used to prosecute any munition workers in contravention of the Munitions of War Act of 1915[161]. If the worker was from a "controlled establishment" firm this gave the Tribunal even greater scope for its powers as labour within such firms was under tighter regulation. Misdemeanours included such things as petty theft, poor time keeping, too much sickness or to being caught sleeping when employed upon a night shift. This Tribunal was also used for arbitration between munition workers and their employers for matters such as pay and conditions or being denied a leaving certificate if the munition worker wished to work for another firm[162]. With these committees operating (amongst others), this demonstrates how comprehensive the control and organisation of both firms and their workforce had become by the war's culmination.

[159] NA MUN5/363/1121.24/4 A greater discussion of the late-war activities of the C.A.O.C. is given in Chapter 6.
[160] See NA LAB2/321/ED27846/1918 for the minutes and composition of this Labour committee.
[161] See Annex 5 for a summary of this Act.
[162] See NA LAB2/53/MT145/1 & LAB2/61/MT145/6/1917

5.12 Armaments and Munitions Production

Manufacturers that were machining shells, manufacturing fuses or components of either had slightly increased by 1918 to 40 firms. One such late-war firm, which turned to manufacturing fuses for the first time was the Singer Motor Company [135].
The following table 11 (overleaf) summarizes Singer's fuse production between 1916 and 1919 and also the frequent changes in contracts; the scaling up of production as they became accustomed to their manufacture; and also the gradual decrease of the contact price from initially 13 shillings and 3 pence per fuse in 1916 to 8 shillings and 2pence by 1918:

Table 11: Singer & Co. Ltd. Fuse Production 1916-1919

Contract Date	Contract Number	Product	Quantity	Rate Per Week	Price Per Fuse (includes Packing & Delivery)	1st Delivery From	Expected Completion Date
28/04/1916	94/F/585	Fuse No.80 MkVII	100,000	1,500-2,000	13s. 3d.	01/05/1916	31/08/1916
30/11/1916	94/F/1017	Fuse No.80 MkVII	continuous	20,000	11s. 6d.*	01/08/1916	31/03/1917
01/04/1917	Continuation for 94/F/1017	Fuse No.80 MkVII ¢	continuous		11s. 6d.	01/04/1917	30/04/1917
	Continuation for 94/F/1017	Fuse No.80 MkVII ¢	continuous		9s. 6d.	01/05/1917	30/06/1917
	Continuation for 94/F/1017	Fuse No.80 MkVII ¢	continuous	25,000	9s.	01/07/1917	
01/01/1918	2 Month Extension and Termination for 94/F/1017	Fuse No.80 MkVII ¢	250,000	25,000	8s. 2d.	01/01/1918	28/02/1918 €
07/02/1918	P.M./F/4365	Fuse No.131 MkIIIC	continuous	rising to 50,000			
22/03/1918	Continuation for P.M./F/4365	Fuse No.131 MkIIIC	continuous				
15/06/1918	Continuation for P.M./F/4365	Fuse No.131 MkIIIC	continuous				
13P/1243	Termination for P.M./F/4365	Fuse No.131 MkIIIC	Total to be delivered not to exceed 501,856				06/03/1919

Notes: * For any fuses delivered after 13/11/1916

¢ Fuses could now be made if the M.O.M. so required in cast iron, steel or malleable iron instead of just brass, likely due to shortages of the later.

€ It was noted that Singer did not meet this deadline as it was heavily engaged in switching production to the No.131 fuse and thus only around 120,000 Type No.80 fuse had been produced for this contract by the end of February 1918.

Sources: NA MUN4/5302/ODE71 and MUN7/16

Despite there being a greater number of firms like Singer manufacturing shells and fuses within the late-war cluster, by January 1917, shell production had already peaked. This was mainly due to the fact that Coventry firm's output now switched to the 218 national shell and fuse factories the Ministry of Munitions had in operation for just such production[163]. This shift in emphasis for the late-war cluster, moving away from purely shell and fuse contracts, isn't easily observable within Table 12 as the percentage of firms undertaking shell and fuse manufacture only declines by one percent. This can be accounted for by Coventry remaining a national centre for shell and fuse component manufacture, despite many local firms no longer assembling the complete item. To say that complete shell and fuse manufacture was winding down within the cluster would be misleading as this work was still being undertaken by many of the larger firms such as Daimler[164], Humber and Standard, amongst others, but it was now no longer the manufacturing receiving their greatest attention. This can even be seen even for the National Fuse and Filling Factory [161], managed by White & Poppe, who reduced their fuse output and now assigned part of their spare capacity over to making aeroplane wings[165].

What the late-war cluster began to switch over to producing is described by the editor of *Coventry and its Industries Official Handbook* as: 'Aeroplane production has been undertaken on a big scale, and many completed machines, built from wing to tail tip in the city, are [now] being produced'[166]. This increase being noticeable within Table 12:

Table 12: Shift in Armaments & Munitions Production

	Total No. of Firms	No. Manufacturing Shells, Fuses & Components	% of Total Firms	No. Manufacturing Aeroplanes, Aero Engines & Components	% of Total Firms
Mid-War Cluster	88	29	33	25	28
Late-War Cluster	137	44	32	44	32

[163] This is compared to just 4 of these national factories in place in 1914. *Glasgow Digital Library* (see bibliography web-based sources)
[164] For example, Daimler between 1916 and 1918 had peaks of 2,000 12-inch shells per week. Ultimately they produced more of this type of shell than any other commercial firm in Britain; Frost (1920) and Thoms & Donnelly (1985) p74.
[165] *The Limit* No. 8 February 1919 'Exeunt Aeroplane Wings' & Hassell (2003)
[166] *Coventry and its Industries Official Handbook* 1918.emphasis added.

Some motor firms in the late-war cluster responded by entering into aeroplane and aero-engines manufacture for the first time. For example, Humber [86], Maudslay [95], Swift [145 & 146], and Singer [135] all entered into aero-engine manufacture from 1916 onwards. However, the significant change was the vast quantities of aeroplanes and aero-engines Coventry firms were now asked to manufacture. Daimler [60 & 61] was discussed in section 5.4 as having entered aero-engine and aeroplane manufacture for the first time receiving a contract for 200 B.E.2c reconnaissance and artillery observation machines. Whereas now, within the late-war cluster, they were being tasked to build 1,500 R.E.8 general purpose aircraft.

The need to manufacture in larger quantities also applied to aero-engine firms within the late-war cluster. Siddeley-Deasy [134 & 134], who had received an order to manufacture 300 R.A.F.1a engines in 1915 were now receiving total orders for 11,500 puma aero-engines, some of which are shown in Figure 24 (overleaf). These engines cost around £900 each and took 1,380 man-hours to manufacture[167]. The fact Siddeley-Deasy decided to dedicate its energies towards aeroplane and aero-engine manufacture (particularly the puma aero-engine), transforming it from a modest company employing 400 workers in 1914 to one with 6,000 by December 1918 working across a hugely expanded 25-acre Parkside site[168].

[167] *Flight* 1st April 1943 p337. (see bibliography web-based sources)
[168] *Flight* 12th December 1918 p1418

Figure 24: Ten days average output of Siddeley-Deasy 'Puma' aero-engines awaiting dispatch from the Parkside Works [133] October 1918

Source: *The Employers Quarterly* p48

According to section 5.9 tanks were now seen as potentially war winning weapons and therefore hundreds were needed and this requirement was also placed upon firms within the late-war cluster. The Coventry Chain Company [31] became the main firm producing the tracks which transmitted their power onto the ground. They also manufactured the smaller chains used inside the tanks engine, gearbox, clutch and driveshafts[169]. Daimler [60 & 61] designed and manufactured the early tank engines by adapting their 105hp sleeve-valve motor vehicle engines, and along with Rover [122-126], they both manufactured many of the gearboxes which went into early types of tank[170].

[169] *The Link* (1919-1921) p62.
[170] Frost, (1920) p176 and Robson (1988)

By the end of hostilities the Ordnance Works [44-46] had assembled 111 complete Mk.IV tanks, but at their Scotstoun Works in Glasgow, although much of the armour-plate was produced in Coventry[171]. The main machine gun selected for use in British tanks was the British-made French Hotchkiss machine gun and it was the Coventry works which produced these, as well as supplying French, Belgium, Romanian, American and Russia requirements. It is noted that the Hotchkiss Artillery Works [83, 84 & 85] at the beginning of 1916 were only averaging around 30 complete guns per week. By the end of 1918 this figure had rose dramatically to 420 machine guns per week[172]. The total output of Hotchkiss machine guns from the end of December 1915 (during which month the first 9 guns for the British Government were delivered) to the close of 1918 was 35,381[173]. From this total 26, 000 were delivered between February 1917 and November 1918, demonstrating how productivity had increased and also how standardized mass-production had swept aside small batch production which prevailed in the early and mid-war clusters[174].

[171] Bacon (1920) Appendix IV pp384-386 and Childs (1999) Part1: Chapters 2 & 4 and Nowell (1927)
[172] MUN5/377/1410/4
[173] MUN5/377/1410/3 p1
[174] H.M.S.O. (1920) *The History of the Ministry of Munitions* Part V Chapter 3 pp19, 22-23. From 1916 onwards Hotchkiss turned to local sub-contracting as another means to increase output.

Figure 25: The Hotchkiss et Cie. Artillery Works [83, 84 & 85], Far Gosford Street c.1918, looking South

Source: Hotchkiss (c.1920s) *A Souvenir of a Visit to the Hotchkiss Works*

A final sector within the late-war cluster which continued to growth was that of the city's electrical engineering firms involved in magneto production. As noted in section 5.4, ML Magneto was one such firm which immediately turned to producing them within the early war cluster. According to section 5.8 they continually expanded their manufacturing capability which necessitated moving to larger premises (figure 20). An indication of the growth of this firm; the expansion of this sector within the late-war cluster; and also the rise of a British magneto industry, is given by examining their production figures. During October 1914 they were producing just eight magnetos per week; by October 1918 this was now 800 magnetos per week in a variety of types[175].

[175] *Flight* 20th February 1919 p257.

5.13 Summary of Coventry's Armaments and Munitions Cluster 1914 - 1918

This chapter has discussed and mapped the armaments and munitions cluster for Coventry during the First World War. Three different time periods were examined in detail and all the firms and institutions that could be identified as internal to the armaments and munitions cluster were tabulated and mapped. Table 13 (overleaf) now provides an overall summary of the changing patterns within this cluster through the First World War.

By comparing column 2 (early war cluster) with column 4 (mid-war cluster), the cluster expanded at its greatest rate between December 1914 and December 1915. This is quantified as the cluster more than tripled in size as a result of the 'Shells Crisis' and the setting up of the Ministry of Munitions and the Coventry Armaments Output Committee. Furthermore when comparing the growth between the early and mid-war cluster with that of the mid-war and late-war cluster the number of new entrant firms slowed down towards the end of the war by a factor of half. In other words, the cluster was expanding at twice the rate during mid-war period when compared to the late-war period. This suggests that both positive and negative factors need to be identified which may have either enticed new entrants into the cluster at specific time periods or may have hindered them joining. Perhaps Swann's ideas (addressed in chapter 2) such as congestion effects may have been at work within the cluster. Another pattern which emerged by the mid-war period and continued to increase in the late-war cluster was the rise in stamping, pressing and forging firms. Table 13 shows this sector changed from zero firms within the early war cluster, to have by the war's end, 32 firms serving the cluster and national requirements. Therefore clearly the demands for munitions provided a major impetus for firms of this sector.

Another observation is of a more general nature: that of the adaptability of the cluster. It was noted in all three clusters that at each time the main armament or munition tasked to produce changed in emphasis.

Table 13: The Coventry Armaments & Munitions Cluster December 1914 – November 1918

	Early War Cluster Map1	(Shown on Map2 & 3)	Mid-War Cluster Map2	(Shown on Map3)	Late-War Cluster Map3
Firm Typology	**Coventry's Armaments and Munitions L.I.C. December 1914**	**New Entrants Between January 1915 and December 1915**	**Coventry's Armaments and Munitions L.I.C. December 1915**	**New Entrants Between January 1916 and November 1918**	**Coventry's Armaments and Munitions L.I.C. November 1918**
Cycle, Motorcycle & Motorcar Manufacturers	**9**	**21**	**30**	**4**	**34**
Component Manufacturers	**11**	**25**	**36**	**14**	**50**
Machine Tool Manufacturers	**4**	**5**	**8**	**8**	**16**
Pressing, Stamping & Foundry Firms	**0**	**11**	**11**	**21**	**32**
Armament Manufacturers	**1**	**2**	**3**	**2**	**5**
Total Factories =	**25**	**63**	**88**	**49**	**137**
Support Institutions and Infrastructure	**5**	**5**	**10**	**3**	**13**
Total Cluster =	**30**	**68**	**98**	**52**	**150**
		← Increase (+) →	**327%**	**← Increase (+)→**	**153%**

At the beginning of the war it was vehicular transport. By the mid-war period many engineering firms were tasked to produce shells and fuses - products which would have been alien to many. By the end of hostilities mass-production of war-winning weapons such as aeroplanes, aero-engines, tanks and machine guns was being asked of the cluster. This rapid adaptation and switching of production suggests that the city's industry was highly receptive to any new wartime demands placed upon it. However, what is left unexplored is how and what mechanism(s) firms used to achieve such a rapid and harmonious transition under wartime conditions. Also how local businesses and the Ministry of Munitions played a role in bringing about these changes and how this evolving armaments and munitions cluster can be conceptualised in relation to the ideas discussed in chapter 2.

These questions demonstrate the need for a further more intensive and qualitative examination of some of the constituent parts of the cluster, namely particular key firms, support infrastructure and institutions and the linkages or relationships between them. For this a smaller range of these shall be examined for each of the three time periods in order to understand ultimately how the clusters operated and why was it largely successful. The following second analysis chapter will now address these questions.

Chapter 6: Understanding the 1914 – 1918 Coventry Armaments and Munitions Cluster

The previous chapter highlighted the existence and evolution of a local industrial cluster of armament and munition firms in Coventry between 1914 and 1918. This final analysis chapter explores the processes underlying these patterns, and in so doing, conceptualizes the types of industrial clustering exhibited by the armaments and munitions sector in Coventry. The chapter begins by discussing the significance of Daimler in the early war cluster. In addition, the roles of some of the early-war business support institutions are discussed. This enables the type of cluster that characterised the early development of the armaments and munitions sector to be revealed. The second part of the chapter examines the impact the Ministry of Munitions played upon and within the cluster from mid-1915 onwards. In particular the significance of the local armaments committee in shaping this mid-war cluster is shown. The third and final part discusses the late-war form taken by the armaments and munitions cluster with a particular emphasis on innovation.

Part A – The Early War Cluster: August 1914 to Spring 1915

"Nucleated Hub-and-Spoke"

6.1 Recapping the main features of a hub-and-spoke cluster

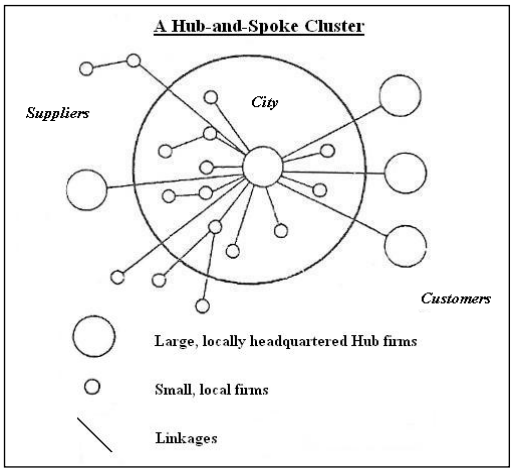
Before discussing the type of cluster model which typifies the early war phase, it is timely to summarise the key constituent features of a hub-and-spoke cluster.

Table 14: 'Idealized' Features of a Hub-and-Spoke Cluster

1. Business structure dominated by one or several large, vertically integrated firms surrounded by suppliers.
2. Substantial intra-cluster trade amongst dominant institutions and suppliers.
3. Key investment decisions made locally, but spread out nationally.
4. Long-term contracts and commitments between dominant firms and suppliers.
5. High degrees of cooperation and linkages with firms both locally and externally.
6. Labour market internal to the cluster and less flexible.
7. High rates of labour in-migration, but less out-migration
8. Evolution of unique local cultural identity and bonds
9. Specialized sources of finance, technical expertise and business services which are dominated by large firms.
10. Absence of trade associations that provide shared infrastructure – management, training, marketing, technical or financial help, i.e., mechanisms for risk sharing and stabilization.
11. Strong local government role in regulating and promoting core industries in local, provincial and national government.
12. A high degree of public involvement in providing infrastructure.

Source: Summarized from Markusen (1996) p297, Figure 1, p298 Table 1 and pp302-304

Figure 26: A Typical Hub-and–Spoke Cluster



In what follows, these general characteristics are related to the early war armaments and munitions cluster previously identified in chapter 5 part A.

6.2 Daimler August 1914 to Spring 1915 – An example of an early war "hub" firm

This section shall begin by examining the city's largest motor firm of Daimler which was one example of a "hub" firm. This firm is chosen for detailed analysis partly due to the evidence available, but also because it began producing a range of munitions immediately war was declared. As may be recalled from the previous chapter, Daimler was immediately involved in producing staff cars, lorries and ambulances (including requisitioned, converted and newly manufactured). They also entered into manufacturing aero engines (based on licensed French designs) and aircraft (based on standardised Royal Aircraft Factory designs) for the first time in 1914.

In 1910 the Birmingham Small Arms (B.S.A) rifle firm had merged with Daimler as the former had entered into motorcar production but with limited success[176]. As a result B.S.A. placed two directors of its own on the board of Daimler and for Daimler, both Edward Manville and Percy Martin, became leading figures on B.S.A's board. Within four years a profit of £430,000 was generated and Daimler was therefore in a strong financial position at the beginning of hostilities to risk entering into the uncertain manufacturing of aero-engines[177]. Daimler also had financial security as it could rely on the support of its parent firm. Despite this merger, Daimler was largely still self-managed with key investment decisions made within the cluster and thus confirms to the third idealized feature in the proceeding table 14.

It is likely Daimler would have been encouraged to enter into aero engine manufacture as shortly after the amalgamation with B.S.A (between 1910 and 1911) the later had experimented with a Lanchester designed aero-engine which proved a failure[178].

[176] For a greater discussion on this merger see Lloyd-Jones & Lewis (2005)
[177] *Arms & Explosives,* November 1913 as cited in Trebilcock (1969) p. 489.
[178] Montagu & Burgess-Wise (1995) *Daimler Century*, Chapter 5 *Sleeve Valves Go To War*, p163.

This shows that Daimler had acquired some limited pre-war experience with aero-engine development (through B.S.A.), and in this instance relied upon long-term specialized and external sources of technical expertise from Lanchester, which it then attempted to perfect and make a commercial success[179]. These features confirm to the fourth, fifth and ninth idealized features in the proceeding table 14.

In addition, Daimler also enjoyed the engineering influence of B.S.A. who were said to have 'perfected the repetition system', which meant the firm found 'itself in a pre-eminent position in whatever industry it desired to participate'[180]. This meant that, between 1910 and 1914, B.S.A.'s influence had spread to Daimler and in particular when Edward Manville, Chairman of Daimler, acquired the rights to manufacture the American designed 'Silent Knight' engine, it was largely through B.S.A. engineering practices which Daimler could perfect its manufacture and ultimately achieve financial profitability. This again reinforces the fifth point in table 14 that Daimler had a high degree of co-operation and linkage (in this instance the diffusion of engineering practices) with its external parent firm.

Furthermore the experience gained from the successful manufacture of the Knight automotive engine eased the transition for the immediate manufacture of the Gnome aero-engine in 1914 as 'many of the operations – including making the cylinders – involved turning relatively large components' which the firm had perfected in the manufacture of the sleeves for the Knight engine[181]. Daimler was therefore a firm which showed a continued path dependency – namely repeating the successful knowledge/technological acquisition from external firms or individuals. With the declaration of war, they once again were able to rely on this practice and secure the exclusive rights to manufacture the Gnome engine in Coventry through the French firm's London agents.

[179] Frederick Lanchester was Daimler's consulting engineer for 20 years and also the owner of a motorcar manufacturing business in Birmingham of the same name.
[180] Ibid, Trebilcock (1969) p489. B.S.A. had been producing guns and ammunition since 1861 and certainly followed American practices in this respect with the inter-changeability of parts and repetitious production.
[181] Montagu & Burgess-Wise (1995) p164.

This section discussed how Daimler had substantial long-standing external linkages to other regional engineering firms, namely B.S.A.; for management, capital and engineering practices; further linkages to Lanchester in Birmingham for design work, and finally to American and French firms for their initial technology acquisition. These reasons explain to some extent why motor vehicle firms such as Daimler were able to enter into armaments and munitions production as soon as war commenced. Similar reasons therefore could apply to other motor firms within the city and highlight the complexity of factors which might have facilitated entry into the early war cluster. Having demonstrated how Daimler at the beginning of the war conformed to points three, fourth, five and nine in table 14, the next section will highlight other reasons as to why it was a "hub" firm. Additionally it will give examples of what are termed in Figure 26 as 'small, local firms' which help supply the "hub" firm in some capacity.

6.3 Daimler August 1914 to Spring 1915 – A "Hub" firm situated within a network of key local suppliers

Another way Daimler may be viewed as an early war "hub" firm situated within a hub-and spoke cluster can be drawn from its position within the supply chain of the cluster. Before the war, it had made substantial investments into some key local suppliers. Two of these large investments were due to the fact that Daimler wished for an increased supply of chains and forgings[182]. Thus in 1907 Daimler financed, to the degree of £30,000, the relocation and reformation of the Coventry Chain Company from their original small Dale Street premises to a large purpose-built factory at Spon End[183]. Daimler also placed two representatives of their own on Coventry Chain's board and therefore maintained a controlling influence there. Coventry Chain also formed a subsidiary company that of Coventry Repetition which also became a supplier of items such as nuts and bolts to Daimler.

In the same year Daimler also invested in Albion Drop Forgings who were able to use this capital for new machinery to increase their output.

[182] Lloyds Bank Archive (LBA) B379a.16 6th February 1907 as cited in Beaven (1994)
[183] Tripp (1956) *Renold Chains* p88 & Ashby (2003) *Spon Street & Spon End* p135.

As a result, between 1909 and 1912, Albion's turnover increased from £9,000pa to £30,000pa[184] and by 1914 this had again increased and stood at £60,000, all largely through the increased demands placed on them by Daimler. Close geographical location also seemed a factor in this decision to invest in this key local supplier as Albion built their new factory in 1906 close to Daimler's Radford factory and during the war the two were set on either side of the Radford Aerodrome[185].

In this new factory Albion continually invested in new larger machinery, for example a 25cwt ordered from the local heavy machine tool firm of Brett's Patent Lifter and which was described by them as 'far in advance of anything we had used before'[186]. This shows the presence of some intra-cluster trade between different supplier firms and this confirms with the 2nd feature in table 14. Between 1906 and 1913, Albion further increased its plant with an additional 15 drop hammers and again the firm opted for ever larger plant this time up to 45cwt. By 1913, the firm continued this trend by installing larger 3 ton batteries designed to produce such work as 'motor crankshafts and front axle beams and such forgings as heavy steam valves for the general engineering industry'[187].

These constant additions to plant, accruing from Daimler contracts, meant the firm, when describing its history, could state that 'this constant progress and installation of up-to-date equipment meant that in 1914 the company was an important member of the drop forging world and able to make a very good contribution to the war effort'[188]. So it would seem one crucial early-war factor for entry into munitions was the possibility of firms possessing modern, recently installed plant which they then needed to keep fully occupied. Also this highlights the strong backward linkages between this local drop forging firm and motor car assembler. Therefore if a "hub" firm such as Daimler entered into munitions production during 1914 it is likely it would also entice its heavily dependent key local suppliers along with it.

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[184] LBA B379a/18 9th August 1909 as cited in Beaven (1994)
[185] See previous chapter, map 3 and the close proximity of factories 2 Albion Drop Forgings and 61Daimler.
[186] Anon, (undated) *Albion Drop Forgings Co. Ltd.* Coventry Archives.
[187] Ibid,
[188] Ibid.

This helps to suggest one reason at least as to why as many as 25 firms were noted in chapter 5 section A entering into armaments and munitions immediately during 1914. This examination of Daimler and some of its key suppliers demonstrates that Daimler was a "hub" firm embracing some vertical integration through backward linkages to key suppliers such as Coventry Chain and Albion Drop Forgings. It also highlights the existence of these smaller, local firms which were heavily dependent through financial and managerial linkages to their "hub" firm. Furthermore their own growth and profitability was heavily associated with their strong linkages as key suppliers to Daimler. All of these features conform to points one, two and four in table 14.

Having now identified the existence of two types of firms, the linkages between them, and having revealed some of the reasons for entry into the early war cluster, it is also important to note that other entities played an active role within the cluster's operation. Feature 10 in table 14 suggests an absence of trade associations within a hub-and-spoke cluster and this is where the early war Coventry armaments and munitions cluster differs from Markusen's (1996) model. The next section will therefore examine the role of two early war support entities, one being a trade association which worked alongside some of the 25 munition firms and the other being the city's own branch of the Chambers of Commerce which was involved with the majority of firms.

6.4 Support Institutions within the Early Cluster – "Business As Usual" and "Hub-firm" led

This section shall explore the operations of two of the early war support institutions operating within the cluster. This is necessary as trade associations are additional entities which affect the linkages between firms and therefore the clusters form and operation. This relates to features 10 and 11 in the proceeding table14.
First the role of the Cycle and Motor Cycle Manufacturers and Traders Union Limited (C.M.C.M.T.U.) will be analysed and secondly the Coventry Chambers of Commerce (C.C.C.). What shall be revealed is how these local support entities operated alongside early munition firms and if these confirm to what is expected to be found in a hub-and-spoke model.

The Cycle and Motor Cycle Manufacturers and Traders Union Limited (C.M.C.M.T.U.)

One of the leading trade associations for Coventry firms was the nationally recognised C.M.C.M.T.U, founded in 1890 and by 1914 still based in the city centre[189]. Its membership included nearly all the city's cycle, motorcycle and related component manufacturers and by the wars beginning totalled 272 firms from all the leading cycle and motorcycle manufacturing centres of Britain such as Wolverhampton, Birmingham, Nottingham and London. Its function before the war was to organise trade fairs, stimulate export trade and promote co-operation amongst the trade generally. The following Table 15 lists the Coventry based members by September 1914:

Table 15: Coventry based members of the Cycle and Motor Cycle Manufacturers & Traders Union Limited (C.M.C.M.T.U.) September 1914

Firm Name	Firm Name	Firm Name
Bayliss, Thomas & Co.	Gloria Cycle Co., Ltd.	Rex Motor Manufacturing Co., Ltd.
Bluemel Bros., Ltd.	Hazlewoods, Ltd.	Rotherham & Sons., Ltd.
Bramble Manufacturing Co., Ltd.	Hobart Bird and Co., Ltd.	**New Rover Cycle Co., Ltd.**
Calcott Bros., Ltd	Humber Ltd.	Rudge-Whitworth, Ltd.
Centaur Co. Ltd.	Lea & Francis Ltd.	Singer & Co., Ltd.
Clark, Cluley and Co.	Middlemore & Lamplugh, Ltd.	Sparkbrook Manufacturing Co.
Coventry Chain Co., Ltd.	Mills-Fulford, Ltd.	Sterling Metals, Ltd.
Coventry Plating & Presswork Co., Ltd.	Montgomery, W. & Co.	Swift Cycle co., Ltd.
Coventry Swaging Co. Ltd.	Monopole Cycle & Motor Co., Ltd.	**Triumph Cycle Co., Ltd.**
Dingley Bros.	Premier Cycle Co., Ltd.	Williamson Motor Co., Ltd.

Notes: Firms given in bold represent the ones holding central positions in this association's management structure, namely Harry Smith from Rover was President and Siegfried Bettmann, representing Triumph, was Vice-President. Furthermore the second Vice President was a Mr C.A. Hyde, representing B.S.A., Daimler's parent company. In addition Alfred Bednell, a local manufacturer's agent, was the secretary of this union.
Source: MRC. MSS.204/3/1/2

[189] See Chapter 5 maps 1, 2 & 3 marked as C.

An example of how this Union co-ordinated the early war cycle and motorcycle manufacturers is revealed for the Russian motorcycle orders that some Coventry firms succeeded in capturing in the first few months of war[190]. During the negotiations this Union instructed its members; when a second Russian order was seen to be imminent, the conditions by which they should proceed:

1. Each manufacturer to make his own quotation for machines, accessories and spares, according to his own ideas on what he can get for his particular type.
2. Payment to be in cash sterling after inspection at makers works and before packing.
3. The quotation should be handed to the Secretary [Alfred Bednell] of this Union who would negotiate for and on behalf of all manufacturers tendering.[191]

Importantly point 1 reveals the Union did not attempt any form of price fixing across the whole trade, but rather wished to co-ordinate, as an intermediary, their tendering, ordering and delivery for this war order to Britain's ally. This highlights that some manufacturer's trade unions were important in helping firms obtain their first munitions contracts and firms which were members could perhaps become 'first movers' in moving away from supplying their private customers and instead working for the War Office or a foreign allied power within only a few weeks of war having been declared. This therefore is something which goes against feature 10 in table14. In this early war armaments and munitions cluster, the C.M.C.M.T.U. was an example of a trade association which had a strong local presence that provided assistance with management (of contracts) and both marketing and financial advice to cycle and motorcycle firms.

[190] Unfortunately the telegrams between the Union, the Coventry manufacturers and a Colonel Starr in London all seem to have been destroyed and only letters and part transcripts remain.
[191] MRC. MSS.204/3/1/2, Untitled Letters dated 19th and 27th October 1914. Emphasis added.

The Coventry Chambers of Commerce (C.C.C.)

A second and more encompassing support institution was the city's Chambers of Commerce based in the city centre[192]. This Chamber represented nearly all the factories in the city and also commercial businesses such as shopkeepers. It therefore was the main forum for manufacturers and traders to discuss any problems arising from the pressures of wartime. Within only a matter of weeks of the declaration of war, a Coventry Emergency Committee (C.E.C.) was formed and its composition is given below:

Table 16: The Coventry Emergency Committee (C.E.C.) September 1914

Appointed Candidate	Positions	Committees
Councillor Siegfried Bettmann (Triumph & Standard)	*The Mayor*	Executive Committee
Alderman Wyley	*Representing the Aldermen & Councillors*	
Alderman Hewitt		
Councillor Kendrick		
Councillor Orton		
Councillor Poole		
Alderman Drinkwater		Representing the Distress Committee
Mrs. S. A. Griffiths		
Councillor Barnacle	*Chairman*	Representing the Board of Guardians
Mr. H. R. Farren	*Vice-Chairman*	
Mr. E. A. Evans	*Clerk*	
Councillor Jones	*Chairman*	Representing the Education Committee
Councillor Bates	*Vice-Chairman*	
Mr. F. Horner	*Clerk*	
Mr. W. J. Wormell		Representing the Coventry & Warwickshire Hospital
Mr. Edward Manville (Daimler Chairman)		Representing the Coventry Chambers of Commerce
Councillor Wale	*Vice-Chairman*	Representing the Insurance Committee
Mr. J. C. Lee Gordon	*Clerk*	

[192] See Chapter 5 maps 1, 2 & 3 marked as H.

Councillor Instone		Representing Employers of Labour
Councillor Pugh (Rudge-Whitworth)		
Admiral Bacon (Coventry Ordnance)		
Messrs. J. Cramp (Engineers & Machine Tools)		
Alfred Herbert (Machine Tools)		
Edward M. Iliffe (Newspaper Magnate)		
Messrs. T. P. Jackson	*President of the Trades Council*	Representing Trade Unions (Entitled to 3 more members not yet appointed)
Mr. J. Chater	*Secretary*	
Mrs. Bettmann	*Mayoress*	Representing Special Women's Organisations
Miss Crabb	*Nursing Institute*	
Mrs. H. E. Givens		
Mrs. M. A. Keene Miss Seymour		
Mrs. Wyley		
Mrs. Cuffee		For the Soldiers & Sailors Families Association
Mrs. Ewan Rotherham		
Hon. Mrs. Hood		
Miss Helen Rotherham		
Miss Greta Rotherham		
Coventry Philanthropic	*President & Secretary from each of the following Philanthropic Societies*	
Golden Cross Society		
Chapelfields Society		
Earlsdon Society		
Hillfields Society		
Stoke Society		
Foleshill Society		
Great Heath Society		
Mr. F. Cunliffe		Representing the Coventry Co-operative Society
Mr. J. Crompton		
Mr. T. Harris		

Rev. Canon Baillie	*Other Members*	
Rev. R. B. Littlewood		
Rev. T. Goodman		
Rev. R. P. Rea		
Mr. H. Sims		
Mr. J. S. Bold		
Mr. W. Carson		
Mr G. G. Beagley		
Captain Field		Salvation Army
Ward Sub-		
All Saint's Ward		
Bablake Ward		
Cheylesmore Ward		
Foleshill Ward		
Greyfriars Ward		

Source: Coventry Herald (C.H.) 4-5th September 1914

The C.E.C. was formed partly through the amalgamation of the Coventry Chambers of Commerce and the Coventry Corporation (the town council) and it may be seen as the first major step towards greater local control of the city during war-time. In relation to the Coventry Corporation's early involvement in starting this committee, this conforms to feature 11 in table 14, whereby there is expected to find, in a hub-and-spoke cluster, a strong local government role in regulating and promoting core industries locally, regionally and nationally – in this instance Coventry's engineering sector. Furthermore the composition of this committee is largely made up of local councillors and alderman and not engineering employers. For a city with the manufacturing capacity of circa 330 engineering firms, this demonstrates minimalist employer representation and as a result little early war co-operation between manufacturers, the War Office or local government ensued.

Upon examining the role of this committee it was initiated to deal with any immediate disruptions of a general nature caused by the outbreak of war. For example, one policy it negotiated was for support to be offered to women & families suffering financial hardship due to their husbands having enlisted.

As a result, many of the city's leading manufacturers, including Triumph, Maudslay, and the Coventry Ordnance, had to 'fall in line' and offer seven shillings per week, per dependent, and one shilling extra per child under 14[193]. This committee was also instigated in an advisory capacity to help manufacturers with information such as the changes in shipping matters or the avoidance or suspension of patents and licences to subjects of states at war with this country[194].

In relation to the hub-and-spoke cluster as a whole, the C.E.C. can therefore be seen as a local advisory and organisational actor which had weak support from new wartime legislation. For instance it possessed little power to direct labour or material supply and had no financial inducement mechanisms to encourage new or increased munition production. Furthermore both the C.E.C. and the Chambers of Commerce were merely forums for the many new wartime problems to be discussed, such as the city's railway, housing or labour difficulties. They can both thus be seen as a continuation of the pre-war "business as usual" attitude which persisted in the early war cluster where the emphasis to mobilise for war production remained with the respective firm, its directors or an entrepreneur. Furthermore section 6.3 demonstrated that leading "hub" firms (such as Daimler) were also crucial to encouraging other firms to become early munitions producers.

One final observation of both the C.M.C.M.T.U. and the C.E.C. is the dominant part played within them by the large "hub" firms of the cluster. For example, Edward Manville (Daimler Chairman) was elected President of the Coventry Chambers of Commerce in October 1913 and continued in this position right throughout the war and thereby represented the Chamber on the 1914 Emergency Committee. Admiral Reginald Bacon (Managing Director, Ordnance Works.) was Vice-President of the Chamber and represented employers concerning labour issues on the Emergency Committee until he was recalled to active military service in early 1915. The same can be seen within the C.M.C.M.T.U. where the Vice-Presidents were Mr C.A. Hyde from B.S.A./Daimler and the 1914 Mayor Siegfried Bettmann from Triumph and involved with Standard also.

[193] C.H.14/15th, 21st/22nd & 28th/29th August 1914.
[194] C.H.28/29th August 1914 *'Coventry Chamber of Commerce Emergency Committee And Its Work'*

This ‘strength’ in terms of the involvement of the larger “hub” firms in these support entities is more associated with an Italianate Marshallian cluster than a hub-and-spoke cluster[195]. In these Italianate clusters trust is central to firms being able to co-operate and act collectively (Harrison 1992 and Saxenian 1994). It is likely this trust was also present in wartime Coventry as it was still essentially a large provincial town, where nearly all the business leaders socialized or knew of each other. It may have also been driven by patriotism engendering collective activity and also a sense of embeddedness to wider structures and contexts. For example, the urgent needs of the Russian government in 1914 for immediate motorcycles, regardless of type, seems to have led them to approach a Colonel Starr in London, who in turn approached the C.M.C.M.T.U. directly, rather than any single contractor. This then provided an opportunity where several firms could come together to supply the same allied power very rapidly and offer mutual assistance.

This first section has now discussed the form and complexity of Coventry's early war armaments and munitions cluster. It is now timely to summarize its main features in the next section.

[195] For a discussion of the Italianate, Marshallian cluster type see Chapter 2

6.5 Summary of the early war hub-and-spoke armaments and munitions cluster

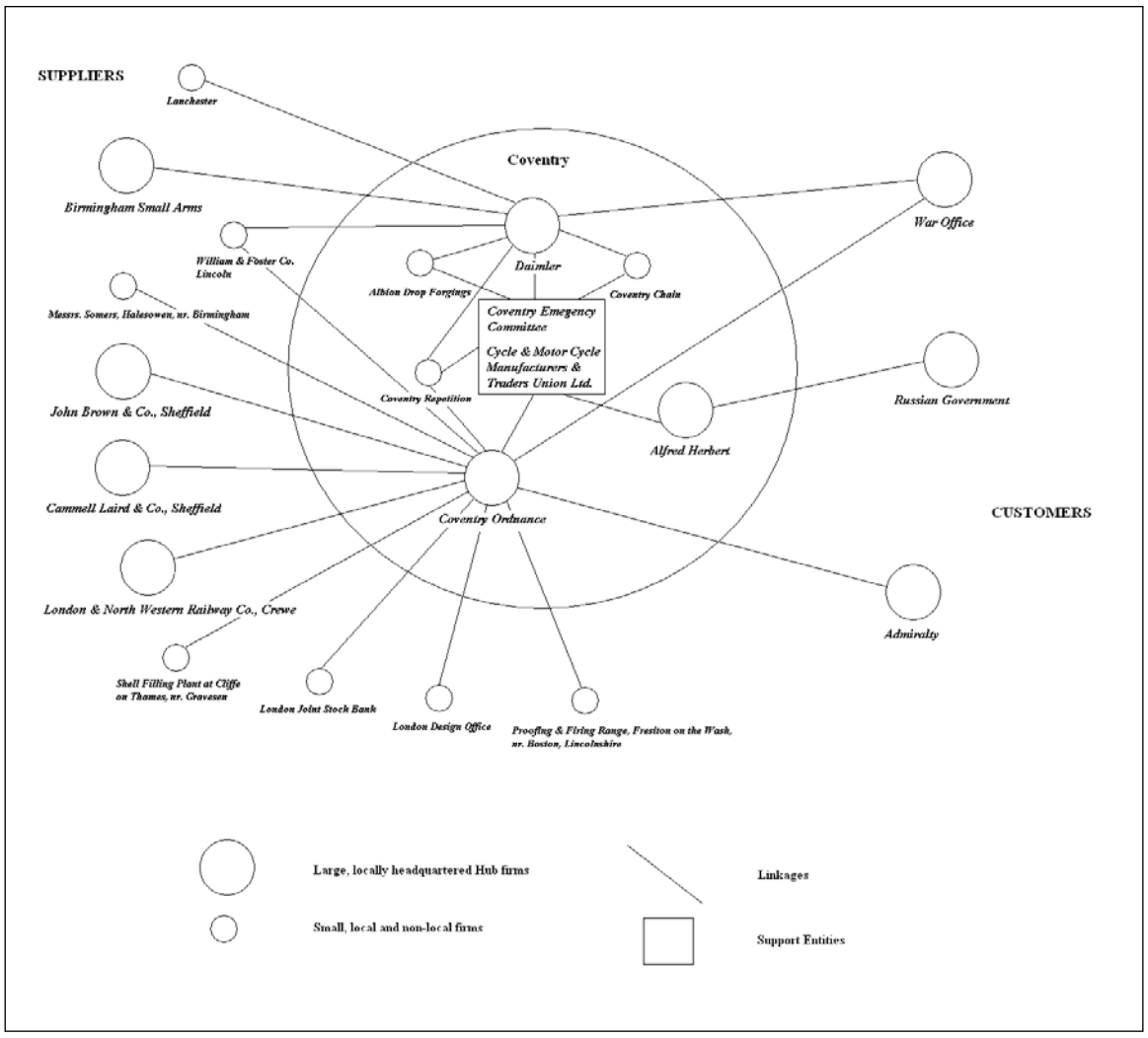
The early war Coventry munitions cluster may be summarized by the following table:

Table 17: The Early War Cluster August 1914 to Spring 1915

- The dominant cluster model which characterized the early war phase of armaments and munitions production in Coventry was a nucleated hub-and-spoke cluster.
- It was nucleated as the cluster comprised a series of "hub" firms, with Daimler being one such example discussed, with Alfred Herbert Ltd. and the Coventry Ordnance Works being two others.
- 'Spoking' out from these hub firms there was a series of small local supplier firms with strong linkages between themselves and their larger "hub" firm.
- The "hubs" firms also had important linkages to firms external to the cluster such as Daimler with B.S.A. and Lanchester.
- One area where the early war Coventry cluster departed from a typical hub-and-spoke model was it had a far stronger local trade association presence which was also "hub" firm led.

The clearest way to summarize the early war cluster is through Figure 27 presented overleaf:

Figure 27: The Coventry Hub-and-Spoke Armaments and Munitions Cluster August 1914 – Spring 1915



Having now analysed the cluster between August 1914 and the early Spring of 1915, the second part of this chapter will now examine the mid-war cluster between late Spring and the Winter of 1915.

Part B – The Mid War Cluster: Spring 1915 to December 1915

A "State-Anchored/Centred Cluster"

6.6 Recapping the main features of a "State-Anchored/Centred Cluster"

Before discussing the type of cluster model which typifies this mid-war phase, it is timely to summarise the key constituent features of a state-anchored/centred cluster.

Table 18: 'Idealized' Features of a State-Anchored/Centred Cluster

1.	Business structure dominated by one or several large non-profit entities, such as government institutions, military bases, a weapons laboratory or a large university and is surrounded by suppliers and customers
2.	Substantial intra-cluster trade amongst dominant institutions and suppliers, but not among others
3.	Key investment decisions made at various levels of government both internally and externally
4.	Short-term contracts and commitments between dominant institutions and suppliers and customers
5.	Low degree of cooperation among local private-sector firms to share risk, stabilize market, share innovation
6.	Labour market national in scope for professional/technical and managerial workers
7.	High rates of labour in-migration, but less out-migration unless government is withdrawing or closing down
8.	Evolution of unique local cultural identity and bonds
9.	No specialized sources of finance, technical expertise or business services
10.	Weak trade associations to share information
11.	Weak local government role in regulating and promoting core activities.
12.	A high degree of public involvement in providing infrastructure

Source: Summarized from Markusen (1996) p299 Table1 & pp306-307.

As discussed in chapter two this type of cluster is more difficult to represent in diagrammatic form.[196] This is why no cluster diagram can be given at this stage, but one shall be developed during the course of this mid-war analysis. In relation to the main characteristics in table 18, the mid war armaments and munitions cluster shall now be discussed.

[196] See chapter 2 for a further discussion on a state-anchored/centred cluster.

6.7 ‘Anchoring’ and ‘Centring’ the mid–war Armaments and Munitions Cluster

As highlighted in chapter 5, after the spring of 1915, the Coventry cluster went through many rapid changes during the course of that year, including 63 more firms entering into armaments and munitions production. These firms, along with the 30 already manufacturing from 1914, were now tasked to produce an increasing variety of munitions such as shells, fuses, aero-engines, aeroplanes and components such a high tension magnetos. Furthermore the number of local support institutions also doubled. By this same time the cluster became heavily influenced by external governmental pressure, brought about by the ‘Shells Crisis’. As a response one prominent organizational change within the cluster was the formation of a local armaments committee (the C.A.O.C.) which was central in adapting and co-ordinating the engineering firms. In this respect, it was this armaments committee which became the main non-profit ‘anchoring’ and ‘centring’ entity within the cluster.

Before this committee was in operation central government began its involvement in the mid-war cluster through surveying the local engineering firms and trying to entice firms into shell and fuse production directly through local exhibitions. After this is briefly discussed, this section shall move onto the main way in which the mid-war cluster was successfully anchored and controlled, through the apparatus of the Armaments Committee. It shall also be shown how the Committee’s Engineer and Secretary were also central to the cluster's operations during this time. This will demonstrate, in relation to table 18, how features 1-3 were present and also how and why feature 9 in this mid-war cluster differed somewhat. After this, the next section shall outline the direct ways in which the Ministry of Munitions anchored, expanded and co-ordinated the mid-war cluster through the provision of capital for firms and also by upgrading and implementing new infrastructure. This discussion addresses features 3, 6-9 and 11 in table 18.

6.8 The Beginnings of State Control – Surveys and Local Exhibitions

One of the first policies initiated in the cluster was a national census of machinery conducted jointly by the Home Office, the Board of Trade and the War Office over the winter of 1914-1915. This was to assess the types and numbers of machinery, particularly lathes, which local engineering firms possessed. These same firms also supplied the inspectors with the numbers being utilised presently for War Office, Admiralty, Allied foreign power or private contracts. They also recorded the number and classes of skilled men they employed on these different types of work[197]. In addition to this survey, the Board of Trade and the War Office instigated a series of munition exhibitions at local labour exchanges and drill halls. These were conducted on the 10th of March 1915 at London, Birmingham, Coventry, Leeds, Sheffield, Manchester, Liverpool, Newcastle and Glasgow. The articles exhibited were 13-pdr, 15-pdr, 18-pdr, 4.5in shells and No.100 fuse. The last three of these Coventry manufactures would go on to produce in great quantities.[198] Photographs of munitions exhibitions in the city's Drill Hall (figure 28 overleaf), at around this time, also reveal that it was not just shells and fuses that local manufactures were being enticed to produce, and perhaps this was a pre-cursor of what was to come for the city later on in the war:

[197] Surviving completed forms for local firms were looked for as a further means to determine which firms became armaments and munitions manufacturers and to also reveal information on the size of these firms and the numbers they employed. However, these completed census sheets appear not to have survived.

[198] H.M.S.O. (1920) *Official History of the Ministry of Munitions*, *Industrial Mobilisation 1914-15* Pt.III Ch.1 *Beginnings of Local Organization* pp8-9

Figure 28: Munitions Exhibitions – Coventry Drill Hall c.1915

Source: Coventry Photographic Collection *'Pictures of Coventry'* (see bibliography web-based sources)

Although these exhibitions were an important first step in educating firms, it seemed that a different approach was needed to fully mobilise the engineering sector for munitions production. That change came in April 1915 when areas of Britain were formed into what were known as "A" areas. Coventry was one such area, designated area number 4 and centred around the Ordnance Works.[199] This form of national division now made it possible for the city to be treated as a single district which could then be mobilised and adapted for munitions production. This was encouraged by the creation of a new local armaments committee.

6.9 The Coventry Armaments Output Committee (C.A.O.C.) – The main non-profit 'anchoring' and 'centring' entity

The most important support entity in the city during wartime was one instigated during the spring of 1915 in direct response to the national shells crisis. It became known as the (C.A.O.C.) and can be considered as the main non-profit entity 'anchoring' and co-ordinating the mid-war cluster as outlined in feature 1 table 18. The beginnings of this committee originated from a general meeting in March 1915 of the city's Machinery, Tool and Engineering Association which passed a resolution to 'offer every support and assistance to the Government in the organisation of the engineering industry'[200]. A preliminary step towards greater co-operation between the city's manufacturers came into being when nine of the leading federated firms formed a joint-committee.[201]

This high degree of co-operation between firms to form a joint-committee is a feature (according to table 18 feature 5) not readily identifiable within a state-anchored/centred cluster. However, this cluster differed in this respect due to the wartime pressures that these manufacturers were facing.

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[199] Who was the principal War Office contractor. H.M.S.O. (1920) *Official History of the Ministry of Munitions*

[200] This was some two months before the setting up of the Ministry of Munitions and before the shells crisis dominated public opinion suggesting that partly it was the city's manufacturers who were pushing for greater organisation of armaments and munitions production which national events merely accelerated.

[201] This comprised the Ordnance Works, Daimler, White & Poppe, Alfred Herbert's, Webster & Bennett, Selson Engineering, Siddeley-Deasy, Maudslay and Coventry Chain. NA MUN5/363/1121.24/2 p2.

For example, the onset of war brought with it the greater restriction of foreign markets; higher labour competition from firms already producing munitions who could offer workers, particularly women, higher wages; restrictions on materials such as castings, including steel motor vehicle wheels, and also a sense of patriotism propelling the firm owners themselves[202]. This is therefore a new context that Markusen's model omits – namely the creation of a state-anchored/centred cluster as a result of wartime pressures which engendered a greater level of co-operation due to firms facing a series of 'crises' which they needed joint-action to overcome.

Returning back to how the C.A.O.C. was formed, it was the above preliminary joint-committee which Alfred Herbert represented when he was invited to the War Office to state the position of Coventry manufacturers on the 15th April 1915. During this meeting, a Mr Booth[203] informed Mr Herbert as to what was being done in other industrial centres such as Newcastle and Birmingham and suggested:

> The formation of a strong local committee, to be made at a representative meeting of the principal manufacturers – both federated and non-federated – which should investigate and report. Information as to the existing facilities in Coventry, obtained by the Home Office and Board of Trade, would [also] be at the disposal of this new committee[204].

Throughout this meeting Herbert was ideally placed to understand what Coventry firms would be able to manufacture and he immediately asked for samples, plans and specifications for 4.5-inch, 8-pdr. shells and No.100 fuses and for a letter from Mr Booth empowering Herbert to proceed with all haste.

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[202] For example, there were discussions in the Coventry Chambers of Commerce about the "impossible" wage competition occurring within the city for the textile firms and the building trade, both suffering from munition manufacturers offering higher wages for girls. Also that as early as December 1914 steel castings and road wheels were virtually unobtainable, at any price, for the city's motor manufacturers. See C.C.C Minutes: 11th December 1914 p33, Vol.9 December 1915, No.1, Vol.2 December 16th 1916 and Annual Report 1916-17 p5.

[203] Who was a member of the Central Armaments Output Committee, Whitehall. See H.M.S.O. (1920) *Official Ministry of Munitions* Appendix VIII.

[204] Ibid, *Ministry of Munitions*. Chapter X, *General Organisation: Midlands* p101,emphasis added. This information was likely the detailed industrial surveys conducted by those government departments in early 1915 and discussed in section 6.8.

Resulting from this meeting another in Coventry was undertaken on the 20th of April 1915 between the city's manufacturers where the following resolution was passed 'That while the Coventry engineering employers are at present time largely engaged upon the production of war material, they pledge themselves to use every effort to assist the Government for increased output of munitions of war'[205]. From this meeting and declaration the Coventry Armaments Output Committee (C.A.O.C.) was formed, which was one of the first of its type in the country[206]. The following table 19 outlines its members and their respective firms once it was in full operation by the summer of 1915:

Table 19: The Coventry Armaments Output Committee C.A.O.C. July 1915

Appointed Candidate	Representing	Principle Trade	Position
Mr. Alfred Herbert*	Alfred Herbert, Ltd.	Machine Tool Makers & Iron founders	*Chairman*
Mr. C. Vernon Pugh*	Rudge-Whitworth, Ltd.	Cycle & Motorcycle Manufacturers	
Mr. Alex Craig*	Maudslay Motor Co., Ltd.	Cars & Commercial Vehicles	
Mr. P.V. Vernon*	Coventry Chambers of Commerce & a Director of Alfred Herbert, Ltd.		
Mr. A. Bednell*	Manufacturing Agent & Secretary of the Cycle & Motor Cycle Manufacturers & Traders Union Ltd		*Secretary*
Mr. W. Cannell*			*Engineer*
Mr. A. S. Hill	Coventry Chain Co., Ltd.	Transmission Chains & Accessories	
Mr. W. C. Macartney	Coventry Ordnance Works, Ltd.	Armaments & Small Tool Manufactures	
Mr. Percy Martin	Daimler Co., Ltd.	Motorcar, Commercial Vehicle & Engines	
Mr. Rogers	British Thomson-Houston Co., Ltd.	Magneto's & Electrical Engineers	
Mr. A. Lord	Selson Engineering Co., Ltd.	Machine Tools & Engineers	
Mr. J. D. Siddeley	Siddeley-Deasy Motor Co., Ltd.	Motorcar & Engine Manufacturers	
Mr. A. E. Bennett	Webster & Bennett, Ltd.	Machine Tool Makers	
Mr. A. J. White	White & Poppe, Ltd.	Engine Builders & Motor Engineers	
Mr. W. Radford	Swift Motor Co., Ltd.	Cycle, Cars, Motorcycle Manufacturers	
Mr. Harry Smith	Rover Co., Ltd.	Cycle, Cars, Motorcycle Manufacturers	
Mr. A. H. Niblett	Humber, Ltd.	Cars, Motorcycles, Engine & Bicycles	
Mr. F. Keegan	Dunlop Co., Ltd.	Wheel & Rim Makers	

[205] Ibid.
[206] Ibid. Note also this committee was sometimes referred to as the Coventry Board of Management, which was merely the management sub-committee of the C.A.O.C. empowered to act on its entire behalf.

Mr. R. W. Maudslay	Standard Motor Co., Ltd.	Cycles & Motorcar Manufacturers
Mr. Kevitt Rotherham	Rotherham & Sons	Watch Manufacturers, Engineers & Motor Components
Mr. C. A. Clarke	Smith's Stamping Co.	Drop Forgers
Mr. W. E. Bullock	Singer Cycle Co., Ltd	Motorcycle, Cycle & Car Manufacturers
Mr. J. Calcott, Junr.	Calcott Bros.	Cycle & Motorcar Manufacturers
Mr. C. W. Hathaway	Triumph Cycle Co., Ltd.	Cycle & Motorcycle Manufacturers

Notes: Marked in blue are the manufacturers already munitions producers before the committee was initiated and marked in red are the manufacturers which became new entrants throughout the course of 1915.
* = Members of the Management Sub-Committee
Sources: Anon (undated)*'King's Visit 1915'* Offprint CA 623.4 box-file, NA MUN5/363/1121.24/4 p3, C.H. 23rd/24th April 1915 &. M.D.T.21st April 1915.

Where this committee differed from similar armament committees in midland cities, such as Derby or Leicester, was it was not used to start latent capacity within the local trade. Instead it was used more to 'organise total effort' from the spring of 1915 onwards[207]. In other words, its role was to fully mobilise the city's entire engineering cluster and convert it from a 'business as usual' to a 'total war' footing by particularly adapting firms for new shell and fuse work which was urgently needed. It was through pursuing this change in emphasis that the committee became the dominant 'anchoring' entity within the business structure of the mid-war armaments and munitions cluster. Alongside the Ministry's influence into this cluster, through the committee, there was also a greater concentration of governmental offices initiated within the cluster at this time[208]. These changes taken together, but in particular the C.A.O.C, is what Markusen would describe as a unique local governance structure[209].

Having identified how this committee came into being and also its composition and functionality this section shall move onto the ways in which the C.A.O.C. began to 'anchor' firms and the mid-war cluster as a whole.

[207] Ibid, *Ministry of Munitions* Chapter X, Pt. II, Midlands p101.
[208] See Chapter 5 map 2 and table 9.
[209] Markusen (1996), p307. Governance structure being defined in this context as a hierarchy which clearly states the positions of individuals and firms and also who is responsible for decision-making and accountability. This hierarchy also being the apparatus to allocate resources and co-ordinate and control armaments and munitions production.

Upon initiation one of the first actions of the committee was to remove the government placed sample shells, fuses and specifications, from the local Labour Exchange, to its own offices at "The Towers" Warwick Road 'where anybody interested can see them'[210]. Another way it immediately began to organize was to assist one firm in the acquisition of lathes to undertake such shell work[211]. No doubt having Alfred Herbert as Chairman of the Management Sub-Committee, and also in charge of the Ministry's Machine Tool Department from the 27th April, 1915, was a distinct local advantage in this respect[212]. As a result of Herbert taking up this wartime post, and being based at Whitehall, whenever a meeting was convened between the Ministry and the C.A.O.C., Mr. Alex Craig (Maudslay), acted in his capacity as Chairman during 1915 and 1916.

Despite beginning to spend most of his time at the Ministry, Alfred Herbert was instrumental in negotiating the C.A.O.C.'s first munition contract of 100,000 18pdr shell cases[213]. These shells were selected by Herbert and the Committee as they were 'particularly suitable to local machinery and the suitability and quality of local labour for the purpose is undeniable'[214]. This last point related to the city's already high proportion of semi-skilled labour and high usage of general-purpose, readily-adaptable machine tools which could be easily adapted to produce these shells[215]. This was also confirmed by a preliminary census the committee took of firms and their plant with a view to ascertaining the total possibilities of Coventry machinery not at the time engaged on munitions[216].

[210] C.H. 23rd & 24th April 1915. See positions D & M on Map2 in Chapter 5.
[211] NA MUN5/363/1121.24/2 p3.
[212] Herbert, 'Memories 10' in *Machine Tool Review*, March-April 1955 p26.
[213] See Chapter 5 section 5.7 for more details on this first C.A.O.C. shells contract.
[214] Anon, Letter to the *Midland Daily Telegraph* likely from the C.A.O.C. Secretary Alfred Bednell, reproduced in the M.D.T. 3rd June 1915
[215] This high proportion of semi-skilled labour was discussed in Chapter 4, section 4.3, as something already in place in Coventry's engineering labour force by 1914.
[216] C.H. 11th & 12th June 1915.

Despite not having the minutes of this armaments committee to ascertain its complete day-to-day 'anchoring' role with firms, what can be noted from its composition in table 19 is that three manufacturers represented on the management sub-committee were all involved in armaments and munitions production from the very outbreak of war (Herberts, Rudge-Whitworth & Maudslay) [217]. It is therefore likely their early experience with munitions would have been invaluable to other local manufacturers who were now seeking advice. In terms of stimulating other manufacturers to take on this munition work, marked in red in the same table, are eight new manufacturers which had become munitions producers through the course of 1915 and who were now also involved in the committee's co-ordinating activities.

A further way this committee 'anchored' the mid-war cluster was by acting as a conduit for financial support as the Treasury deposited with a local bank, £15,000 free of interest to help cover all preliminary work needed within the city and to enable prompt initial payment to be made – something capital restricted small firms often desired[218]. Having speedy access to this capital and also a definite order for 100,000 18pdr. shells, at a guaranteed price, all seem to have been crucial in persuading the city's smaller firms to take on shell manufacture during 1915. This suggests the committee was a source of financial assistance for firms and is one way this wartime cluster doesn't conform to feature 9 in table 18 for an idealized state-anchored/centred cluster.

Further functions for the Committee were to co-ordinate transportation, inspection gauging and the warehousing of the completed shells and fuses locally, relieving these duties from the firms who could then solely concentrate on their manufacture.

[217] See MRC MSS.204/3/1/50 which was originally the minute book of the C.A.O.C. and in 1940 the minutes pasted into the volume were torn out so that it could be re-used. For a summary of the C.A.O.C. between 1915 and 1917, see NA MUN5363/1121.24/2, MUN5363/1121.24/4 and the edited version in the H.M.S.O. (1920) *Official History of the Ministry of Munitions* Chapter X, Pt.II p101-103.
[218] C.H. 11th & 12th June 1915 and MUN5363/1121.24/4 p9. This amount was later recovered from the invoices for the last 20,000 shells produced.

For example, during 1915 whilst undertaking the first shell contract, an important part of the committee's time was dedicated to management in settling the matter of renting a local bonded store for no less than fourteen days output of shells[219] and also for the preliminary expenses incurred in equipping it with a hydraulic banding presses and other necessary plant[220]. Before local firms where in a position to undertake this first contact, representatives of the Committee[221] were invited to inspect how shells were produced at Woolwich Arsenal on June 4th 1915 where they:

> Received the greatest attention from the Government officials who received and conducted them through the shell and inspection departments of the Arsenal, whilst the fullest information was afforded upon the many technical points involved.[222]

It would seem that this overt government policy of rapidly sharing manufacturing information helped to impart tacit knowledge of shell production to the Committee's engineer Mr Cannell. Therefore by the time the first shell contract was being worked on, Mr Cannell, was in a position to be 'advising local manufacturers as to methods of manufacture and as to the adaptation of their existing machinery to this [new munitions] work'[223]. It was also noted that this first shell contract proved of great educational value to local contractors, for the committee's engineer was in constant attendance upon the manufacturing, process by process, and saw to the proper interpretation of drawings and specifications, and ultimately inspection[224].

The complete managerial and organizational 'anchoring' role the committee played in the mid-war cluster is revealed in an interview with Mr P.V. Vernon given to the *Midland Daily Telegraph*. In this, he describes the activities as follows:

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[219] The costs of which amounted to £50-£55 per week and were the main expenses.
[220] MUN5363/1121.24/4 p5, 7 & 9. This bonded store was provided by the Coventry Corporation and was used for final assembly and despatch of the shells. Unfortunately its location could not be found. After the 31st March 1916 the costs of this bonded store were taken over directly by the Ministry of Munitions.
[221] Specifically Mr Alex Craig representing Maudslay, Mr P.V. Vernon representing Alfred Herbert Ltd. and the armaments committee's engineer Mr W. Cannell.
[222] M.D.T. 5th June 1915
[223] M.D.T. 3rd June 1915 and also C.H. 11th & 12th June 1915 emphasis added.
[224] Ibid, *Ministry of Munitions,* Vol.1 Appendix IV and Morewood (1999) *'Pioneers and Inheritors'* pp37-38.

> In the first place there were the negotiations necessary for obtaining the contract. Secondly time had to be spent in ascertaining the sources of supply of material and in obtaining them at a reasonable rate of delivery…..As soon as the manufacturer receives his order for shells [through the C.A.O.C.] he has to make special tools and appliances for turning them out…In many cases manufacturers are rearranging the machines in their workshops for the purpose….Before a single shell can be turned out each manufacturer must have gauges, and before gauges can be made in quantities for the various manufacturers, an original set has to be made, submitted to, tested and passed by Woolwich. From this original set, which is kept for reference, the gauges used by the various manufacturers are made.[225]

It was not just help with gauging the Committee provided; it also solved the problem of inspection for firms. At first, it was intimated that this would be done in Sheffield by the War Office and would involved chemical analysis of the material to be used in the rough shell forgings, which would then, once passed inspection, be supplied to Coventry for machining. The C.A.O.C. suggested that to save time it 'arranged with the steel manufacturers to put their testing apparatus at the disposal of the Government inspector on the spot'. The War Office then accepted the committee's suggestion for this local inspection instead.[226] Local Inspection is confirmed as a munitions inspection office was located (position G on maps 2 and 3), near to the Ordnance Works, who probably also assisted with local inspection and gauging as this was something they had capabilities for[227].

One way the committee exercised its power for greater mobilisation was via sending letters to the various editors of the local newspapers, to then be published. These letters were used as a means by the committee to instruct manufacturers by appealing to their patriotism. One such letter, shortly after the committee was formed, instructed:

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[225] M.D.T. 10th June 1915. A gauge being simply an instrument used for measuring precise conformity, in this instance, measuring the shell case dimensions after machining. These gauges were used in ever increasing quantities within the engineering industry during the war to implement accurate repetitious production and to jointly assist the inter-changeability of parts and the increasing use of 'diluted' semi-skilled labour.

[226] M.D.T. 24th June 1915 and C.H. 25th/26th June 1915.

[227] One example of this assistance was the Coventry Ordnance Works helping with inspection and gauging for the Singer Motor Company when they first entered into the manufacture of No.80 fuses.

> It becomes the clear duty of every manufacturer who has even a single machine tool suitable for any part of this work to use it to augment the output. It is equally clear that every manufacturer should lay aside his private or civil contracts if by doing so he can produce shells…..Public opinion will undoubtedly view the manufacturer who gives preference to his private work in the same way as it looks upon the young able-bodied shirker.[228]

It would appear the committee and the aims of the Ministry of Munitions were largely successful within the city as even in its formative stages it was described by Mr P.V. Vernon that 'there is a great spirit among the local manufacturers - a keen desire to help each other in this work'[229]. The press also confirmed this opinion by stating:

> No more highly skilled work has been employed anywhere in the country than in the local factories, and it is gratifying to add that probably in no engineering centre in Great Britain has there been less friction in the readjustment of wages to meet increased war costs of living, or a more general and hearty co-operation between manufacturers and employees to meet the needs of the Army.[230]

One example of this successful adaptation was the small firm of Farmer and Sons. Prior to the war they described themselves as 'doing general engineering work on a small scale'[231]. By 1915 they commenced the manufacture of 18-pounder H.E. shell cases and so smooth was this firm's adaptation that Boards of Management from other districts were sent to their works in Coventry, to 'see what could be done in a small shop'[232]. It wasn't just the machine tools possessed by firms which the committee adapted for this shell work, as even the engineering workshop at the Coventry Technical College was pressed into service producing 180 shells a week[233]. This reinforces how widespread and dominant the committee's mid-war activities became in accord with feature 1 in table 18.

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[228] Anon, Letter to the *Midland Daily Telegraph* likely from the Coventry Armaments and Output Committee Secretary Alfred Bednell, reproduced in the M.D.T. 3rd June 1915 *Coventry and Munitions of War.*
[229] M.D.T. 10th June 1915.
[230] C.H. 11th & 12th June 1915.
[231] *Coventry Industries Handbook* c.1920 p68.
[232] Ibid, p68.
[233] C.H. 25th/26th June 1915.

As well as a high degree of co-operation an 'open-door' policy also seems to have characterised Coventry firms during this period as William Hillman, speaking in September 1915 about his small shell factory and the leading role women played, suggested:

> 'If anyone else is prepared to follow my example I am prepared to show him that women can make these things and make them properly. He can come and see every operation in making the shell from the beginning to the end.'[234]

This willingness to be overt and to co-operate among adapting firms by sharing shell-making methods and to help breakdown any stereotypes surrounding the use of female labour in engineering shops, are features not readily identifiable with a state-anchored/centred cluster. In fact, according to feature 5 in table 18, a low degree of co-operation among firms is usually the case. However, it must be understood that these munition producing firms were being propelled by expediency and patriotism and less thought given over to pure profit making. Also these firms were working directly for the same customer and not competing against one another under normal market conditions. This appears to be a new context which has not been considered by Markusen or subsequent literature in relation to these idealized cluster models.

Returning back to the activities of the committee and the firms it directed, it was noted at a meeting between the committee's board of management and a Ministry representative, that as early as January 1916: 'there was a general feeling among the members of the board that, as the contractors had learnt their work, it was questionable whether they were justified in maintaining a staff which included a consulting engineer at a salary of £600 per annum and a secretary at £300'[235]. Subsequently Mr Cannell's services were arranged to be no longer needed in Coventry[236]. However, the secretary, Alfred Bednell, seems to have served in his position for the war's duration and it is to the important role this man performed in forming the linkages between the Ministry of Munitions and firms that this section now turns to.

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[234] C.G. 17th Sept 1915.
[235] MUN5363/1121.24/4 p6.
[236] Ibid. p6-7. This highlights how successful the committee was in its 'anchoring' role to mobilize, adapt and educate the city's manufacturers for new armaments and munitions production.

Alfred Bednell was noted in the early-war cluster as the secretary of the national Cycle and Motor Cycle Manufacturers and Traders Union Limited which was headquartered in the city[237]. He was in fact, by trade, a manufacturer's agent before, during and after the war, which meant he would work on behalf of firms to secure contracts. In today's terms he would be considered a free-lance business representative who was approached in order to utilise his extensive business contacts. These contacts stemmed from him having long standing ties with the city's cycle and motor industry including him being involved, as early as 1889, to form once such cycle firm of Messrs. Taylor, Cooper and Bednell. Even at this early time he was employed 'as a representative of the firm…but his intimate acquaintance with the cycle industry is well known among those who have any connection with it'[238].

By 1915 Bednell's importance as the secretary of the newly formed C.A.O.C. can be considered partly why adaptation and the growth in the number of firms was achieved with such ease. This was due to his intimate knowledge of the manufacturing capabilities and inner workings of many of the firms across the entire city. This was the case as the business community in which the local cycle and motor manufacturers operated in continued to hold an emphasis on personal relations throughout the war. The most important location where these were forged was the Coventry and County Club, the unofficial centre of the city's engineering industry[239]. This club was created on the 3rd of January 1899 by a group of Coventry industrialists. Entry into this private social club was highly restricted since the election of members was largely vested in the club committee. Prospective members could be refused entry if they were 'black balled' in the ballot, or if an existing member objected within two weeks of new names appearing on the club's notice board.

[237] See section 6.4 of this chapter. This meant Alfred Bednell had experience in co-ordinating local manufacturers and with dealing with the War Office from the very beginning of the war.
[238] *Cycle Record* 3rd Jan 1891 in *'Lowe's Cuttings'* Vol.18 (1890-1891) pp77-78.
[239] See Chapter 5 Maps 2 & 3 position L. Beaven (1996) p25 and Storey (1985) *'Percy Martin'*, pp167-168.

In its early life this club was dominated by the 'new' industrialists including Alick Sargeant Hill[240], who chaired the early meetings, George and William Du Cros (Dunlop & Swift,) J.K. Starley (Rover) and Alfred Bednell, gentlemen all with strong links with the early cycle and motor industries[241]. However, despite the exclusivity of the club, it did not exclude gentlemen of fairly small firms within the city.[242] It also allowed membership to important managerial staff such as Oscar Harmer and H. Grinyer, both from Alfred Herbert, or Harry Smith from Rover. In addition to this club acting as a 'hub' for creating business contacts between manufacturers and suppliers, it also linked entrepreneurs with agents, solicitors and local bank managers.

By 1915 the membership of this private club was increasing, despite the local cycle and motor trade being almost put on hold for the duration of the war. In the first year of the war alone, membership increased from 222 to 235 members[243]. This increase was partly due to the fact that by January 1915 'all officers of the Army and Navy, stationed at, or on leave in, Coventry be [now] honorary members of the club'.[244] The club further resolved by June of the same year this offer be extended to Allied officers as well.[245] This meant that members could also socialise in military circles as well as business ones throughout the war. The number of members also grew as entrepreneurs saw membership as an opportunity to make new contacts that could potentially lead to munitions deals either directly or as sub-contractors.

[240] Coventry Chain Company, Coventry Repetition Company, Thomas Smith's Stamping Works and also Mayor of the city 1916-1917. See *Former Mayors and Lord Mayors of Coventry* in Bibliography web-based sources.
[241] CA PA578 *Coventry & County Club, Minutes of General Meetings,* 3rd Jan 1899.
[242] For instance C. Foster (Coventry Magneto), B. Riley (Riley Motor Co.), J, Calcott Jnr. (Calcott Motor Co.), S. White (White, Joseph & Sons, watchmakers), W.A. Oubridge (British Piston Ring) and W.J. Grindlay (Coventry Motor and Sundries) were listed, amongst others, as members during the war. CA PA578 *General Meetings 1914-18* & PA578/22/1 *Coventry & County Club, Reports & Accounts, 1913-15.*
[243] Ibid, *Statement of Accounts* ending 31st December 1915.
[244] CA PA578/19/2 *Coventry & County Club, Minutes of General Meetings*, 19th Jan 1915.
[245] Ibid, *Minutes* 15th Jun 1915 emphasis added.

Crucially this was the part Alfred Bednell played in creating the linkages in the mid-war cluster as Harold Nockolds vividly describes his wartime activities there:

> Bednell, who had been the Ministry of Munitions representative in Coventry during the war and knew everyone worth knowing in the district, operated largely from the bar at the County Club, which was the unofficial head-quarters of the motor industry in Coventry and where all the real business was done between manufacturers and their suppliers.[246]

Bednell, it seems, was able to operate from the County Club during the war as it was just around the corner (five properties along in fact) from where the Cycle and Motor Cycle Manufacturers and Traders Union Ltd. held its offices, where he was also secretary.[247] Furthermore this Union relinquished this office space to the Coventry Armaments Output Committee during the summer of 1915.[248]
This meant that between 1915 and 1918 his day-to-day activities were highly localised and this is likely why he could spend his time dealing with munition contracts from the bar of this private member's social club. One noticeable example of how important membership was to a club, such as the one described above, can be seen in the difficulty that the Coventry Simplex Company[249] had in turning to munitions.

According to a taped interview with the founder's son, Mr Leonard Pelham Lee:

Mr Lee: 'When the 1914-18 war came….business stopped overnight and it was a long, long time before he was able to get any more contracts….eventually he got contracts to make shells [not until 1917 it would appear] and then when things got more organised he was able to get contracts for producing petrol electric generating sets which were used for searchlights…[by which time] he was virtually standing or living at the war office'.[250]

[246] Nockolds (1976) *Lucas* Vol.1 p176.
[247] See maps 2 and 3 in chapter 5.
[248] MRC Letter dated 22nd June 1915 from Alfred Bednell to the Management Committee
[249] From 1917 onwards it was renamed Coventry Climax Ltd. the same name which 50 years later, as an engine supplier to many Formula One World Champions, the company became world famous.
[250] *Richardson tapes,* No.32: Me Leonard Pelham Lee and Miss Morris, emphasis added, Lanchester Library.

Upon describing his father's involvement within the business community during the war he and his wife added:

Mr Lee:	'He wasn't a man interested in any of the local activities such as engineering associations or the council [Coventry Corporation], or golf or any of the clubs…and for that reason he didn't meet these people socially'.
Dr Richardson:	'He was not a member of the Draper's Club?'[251]
Mr Lee:	'No'
Miss Morris:	'Nor County I don't think' [referring to the Coventry and County Club already described].

This highlights the importance for Coventry firms to be well connected or networked within the local business community. By 1915 firms such as Complex Simplex were disadvantaged as they did not have the informal access to Alfred Bednell, via being members of the Coventry and County Club. This resulted in them struggling to gain contracts for munitions work, and in fact, it took them a further two years to do so. This reinforces the dominant position that the C.A.O.C. held within the mid-war cluster and also that firms with easier access to its secretary could potentially become munition producers early on in 1915. More could be written of the many contracts that Bednell, acting on behalf of the Committee, succeeded in tendering for and helped assist manufactures with. However, the key insight, which the available evidence suggests, was the C.A.O.C., (through its secretary and engineer) played the dominant part in allowing the mid-war armaments and munitions cluster to adapt and grow into a state-anchored/centred cluster. This was achieved largely through channelling assisted contracts, giving technical and financial support and also by organising many engineering firms in the city (generally the small and medium-sized ones) into a co-operative.

[251] See Chapter 5 Maps 2 & 3 position K. The Draper's Club was another private members club within the city where it was described by a contemporary that 'all your top industrialists and professional people went'. See Beaven (1996) *Re-constructing the Business Community*, p25.

In essence the committee was the key non-profit entity (feature 1 table 18) which central government (external to the cluster) could affect local change and manage and co-ordinate firms, utilising local knowledge and business and social networks, particularly through the Coventry and County Club. The five members of the management sub-committee included Alfred Bednell, but also Alfred Herbert and Mr. P.V. Vernon, (both from Herbert Ltd.). Therefore this machine tool firm was also at the forefront of adapting and co-ordinating the Coventry engineering sector for national interests. This was also formulised by Herbert being immediately empowered to do so by the War Office and also by the Committee being allowed to appoint its own dedicated engineer and secretary, (both paid for out of management fees charged on contracts).

The committee was therefore a governance structure which allowed the coming together of these individuals to offer firms the necessary advice, both technical and administrative, who wished to turn to munitions production for the first time. This largely addressed this need which other support institutions (e.g. the Coventry Emergency Committee or existing local trade associations), were unable to provide in the early war cluster. This is another feature which, according to table 18, is not to be expected in an idealized state-anchored/centred cluster. This pattern of identifying cluster features not expected to be found in a state-anchored/centred cluster is perhaps due to the underdeveloped nature of these cluster models and that they have not been tested before empirically in a wartime economy such as this.

So far this section has discussed how the mid-war cluster was ‘anchored’ and ‘centred’ upon a local armaments committee and in particular the key roles played in this by its engineer and secretary. This was in relation to the idealized features 1, 5 and 9 in table 18. It shall now move onto briefly examining the provision of capital (for firms and the cluster as whole) which were jointly needed to facilitate expansion. This discussion addresses features 3, 9 and 11 in table 18.

6.10 Anchoring the Mid-War Cluster – The Provision of Capital for Firms

The most direct way in which the mid-war cluster was anchored by the Ministry of Munitions was through financing expansion for local munition firms and upgrading the city's infrastructure. First some examples of the large sums which Coventry firms were advanced by the Ministry are given. Second the investment which the Ministry allocated for improving the city's power facilities to cope with a much expanded munitions industry, shall be discussed[252]. The following table 20 (overleaf) summarizes just a few of the many large sums which the Ministry of Munitions advanced firms to increase their plant and machinery to undertake or increase their new munitions work:

Table 20: Ministry of Munitions Capital Investment in Coventry Firms 1915-1918

Date	Firm	Expenditure	Purpose of the Investment
29/11/1915	Hotchkiss et Cie	£45 ,000	To expand plant and machinery to increase machine gun output to 50 guns per week
May-1916	Hotchkiss et Cie	£15, 000	To increasing plant and machinery for the manufacture of spare machine gun barrels
Mid-1916	Coventry Ordnance Works	£188, 000	Extension of plant and machinery for the relining and repair of guns
Jan-1916	Coventry Ordnance Works	75% increase on gauges	Assisted contracts for gauge production No. 94/G/1367
Mar-1916	Coventry Ordnance Works	75% increase on gauges	To increase plant and machinery for gauge manufacture
28/04/1916	Singer Co.	£12,000	For plant and machinery needed to manufacture 20,000 No. 80 fuses per week
03/05/1916	Humber Ltd.	£50,000	For plant and machinery necessary to manufacture 4,000 4.5" H.E. howitzer shells per week

[252] A second example was the Ministry also advanced the Coventry Corporation many thousands of pounds for the construction of new housing, but space precludes being able to go into detail here. See H.M.S.O. (1920) *History of the Ministry of the Munitions*

15/06/1916	Daimler Co.	£254,000	For plant and machinery necessary to manufacture 12-inch H.E. howitzer shells
30/11/1916	Singer Co.	£6,000	To convert and alter the above machinery and tools to manufacture 50,000 No.131 fuses per week
09/01/1917	Coventry Ordnance Works	£89, 000	Extension of plant and machinery for increased production of 4-inch naval guns
Late 1915-31/03/1918	White & Poppe National Shell Filling & Fuse Factory No.10 / 21	£813, 400	Total capital expenditure for building and equipping this national factory

Sources: CA PA699/63, NA MUN 5/377/1410/3, MUN5/189/1410/23, MUN7/167, MUN7/180, MUN7/182, MUN4/5302/ODE71, MUN4/427, MUN5/373/1200/1 and H.M.S.O. (1920) *History of the Ministry of the Munitions*, Appendix IV

Despite the Ministry providing substantial investment, it was also left to firms to use their own capital reserves. Rover, for example during November 1915 placed an order of £14-£15,000 for machinery to undertake shell manufacture (this contract being for the C.A.O.C.) and noted this had to be paid for by the end of that year. This expenditure the firm appeared to obtain from a £30,000 reserve fund their board had sanctioned for just such wartime eventualities[253]. Another way that munition firms could meet the capital requirements was to increase their share capital. In a letter to his shareholders, the Managing Director of Coventry Chain, Alick Sargeant Hill, explained this was how they planned to finance their wartime expansion. He explained to them, with Treasury approval, the firm was to increase share capital from £150,000 of 1913 to £250,000 in July 1915. This was due to the firm being 'urgently pressed for maximum possible output in the shortest possible time'[254]. This suggests in relation to feature 3 in table 18 (key investment decisions) that it was both the firms themselves and the Ministry of Munitions (directly or indirectly through the C.A.O.C.) who provided the investment. Thus these decisions were carried out both internal and external to the cluster itself and could also be dependent upon the type of munition contract entered into.

[253] C.H. 12th & 13th November 1915.
[254] M.D.T. 19th July 1915.

For example, upon examining table 20, apart from Hotchkiss, all the other firms receiving direct external investment were 'controlled establishments' and therefore undertaking munitions contracts directly for the Ministry of Munitions or the Admiralty. This form of direct control facilitated the investment to come from the Treasury as 'controlled' firms were not allowed to take on any private work and therefore any such investment could not be used by the firm for any other purpose. In contrast, if firms took on contracts through the armaments committee (such as Rover did during 1915 for shell making in table 20), then the firm themselves had to finance the necessary plant to undertake the contract. Alongside investment allocated to munition firms, the Ministry of Munitions also upgraded the city's infrastructure to allow an enlarged state-anchored/centre armaments and munitions cluster to operate. It is to this further investment that the following section now addresses.

6.11 Increased need for Power Supplies for Armament and Munition Production

With increasing munition production one of the greatest pressures engineering firms created was on the city's existing power facilities. For example, shortly after the outbreak of war there was an abnormal increase from the Daimler Company which needed an additional 600K.W. of power added to an immediate prospect for a further 500K.W. needed by the Ordnance Works. It was later agreed that the Ordnance Works supply could only be given if there was an agreement by them to suspend or reduce the load between 4:30 and 5:30p.m. on working days[255]. This suggests that even in 1914 the city's power system could not cope with just a few of these larger firms needing more power.Despite these power restrictions in the early cluster, still greater capacity was needed by 1915. This was because the ever increasing demand for armaments and munitions production, both day and night, meant that 'Coventry firms were [now] threatened….with serious inconveniences arising from shortage of electric power'[256]. One solution was implemented by firms themselves with Rudge-Whitworth building and equipping their own electrical sub-station supplying 1,000h.p. alongside 162 other electric motors within its works[257].

[255] CA PA1/4/21/1/3 *Coventry Electric Light Committee Minutes* 12th November 1914.
[256] NA MUN5/363/1121.24/2 & MUN5/363/1121.24/4 emphasis added.
[257] *Rudge Record*

To relieve the situation for the entire cluster the Coventry Corporation Electricity Works placed an order with the British Thompson-Houston Co., Rugby for delivery of a 3,000K.W. turbo alternator. However, by March, they were informed that delivery was indefinitely held up as the Admiralty had commandeered all blading work for Chatham Dockyard.[258] As a result, the firms most in need of this additional power[259] were informed that unless the decision of the Admiralty could be reversed the Coventry Corporation would be unable to meet their needs for increased power and it suggested to these firms they themselves should apply pressure to the Admiralty to resolve the issue[260]. Thus it would seem these Coventry firms had little support from the local council and were in fact left to remedy the situation by themselves. This is evidence of feature 11 in table 18 of 'weak local government role in regulating and promoting core activities' and according to Markusen (1996) is typical for clusters 'anchored' by the state.

Shortly after these instructions both the Ordnance Works and White & Poppe wrote to the War Office pointing out how serious any shortage of electricity would be, and as a result a meeting was held in Coventry between representatives of the Admiralty, the British Thompson-Houston Company and the Coventry Corporation. Such was the national importance of the leading Coventry firms outputs that it was then satisfactorily settled that the blading would be redirected by the Admiralty to be delivered in May and the situation resolved.[261] For these additions the Ministry of Munitions loaned the Coventry Corporation the money needed to implement them, the loan to be repaid at 4.5 percent interest. By December 1915, the agreement was increased with a further loan of £30,278 at 4.75 percent interest advanced to the Corporation[262]. These key investment decisions (feature 3 table 18) made between external government departments, (the Treasury and the Ministry of Munitions), and internally with the town council (the Coventry Corporation), is an additional idealized feature found in a cluster 'anchored' by the state.

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[258] Ibid MUN5/363/1121.24/2 & MUN5/363/1121.24/4
[259] The Ordnance Works, Daimler, Alfred Herbert and White and Poppe, including the new shell and fuse factory they were now laying down and managing on behalf of the Ministry
[260] Ibid PA1/4/21/1/3 12th April 1915.
[261] NA MUN5/363/1121.24/2 & MUN5/363/1121.24/4
[262] Ibid, H.M.S.O. (1920) *History of the Ministry,* Ch. IV. Pt.III *Control of Industrial Equipment* p96.

Overall, electricity consumption increased three-fold in the city during the war due to the additions to existing factories, the greater application of machine tools throughout many of these firms and also the construction of new works.[263] According to the *Official History of the Ministry* as of June 1914 Coventry possessed electric plant to the capacity of 12,000KW. During the course of the war the Ministry installed or authorised an additional 13,200KW by October 1918.[264] Despite this, by the end of the war, power supply, was once again becoming a restricting factor on the cluster expanding still further and may be one of the reasons why there was a drop in the number of new entrants towards the end of the war.[265] This is an example of a congestion effect as identified by Swann (1998) in chapter two.[266]

Having now outlined how the Ministry expanded the city's power facilities, one additional example of how the Ministry was at the centre of expansion was to increase accommodation and the instigating of official billeting in the city for munition workers, however, space precludes discussing this in-depth[267]. Suffice to say both examples demonstrate that the cluster had very high levels of labour in-migration and also that this labour market was national and international in scope. These two features relate to points 6 and 7 in the proceeding table 18, and the Ministry's investment in housing is an additional example of key investment decisions (feature 3) being undertaken by central government, external of the cluster itself.

6.14 Direct control – Key Coventry firm's become "Controlled Establishments"

One final complication to the mid-war cluster was the Ministry of Munitions not only exercised control through the local armaments committee, it also commandeered the most important firms and made them 'controlled establishments'.

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[263] Hannah (1979) *Electricity Before Nationalization* p59.
[264] Ibid, H.M.S.O. (1920) *History of the Ministry*, Ch. IV App. XVII p105.
[265] See previous chapter 5 p.104 Table 13.
[266] An additional late-war congestion effect was the shortage of food within the cluster by 1917/18. This was brought on by the city's rapid population increase - from an expanding munitions cluster - and food allocation was based on pre-war population levels. The situation was compounded by rationing due to the German unrestricted submarine warfare by 1917/18. For a further discussion on this problem see Bryant (1987) 'Politics of food during the First World War: Birmingham & Coventry' Warwick University thesis.
[267] See H.M.S.O. (1920) *History of the Ministry* for a greater discussion on the housing expansion instigated in Coventry from 1915 onwards.

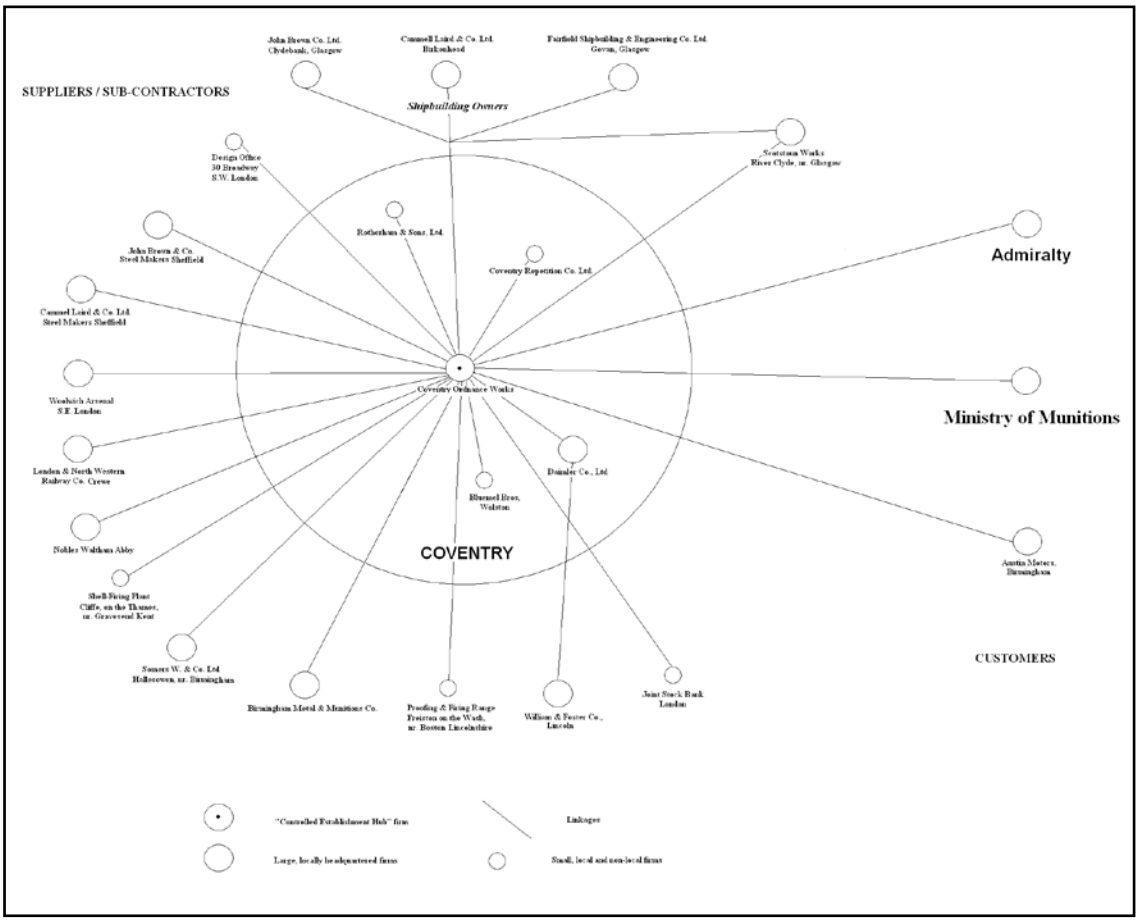
According to chapter 5 by the end of 1915 some 48 local firms were taken over in this manner with the Ordnance Works and Alfred Herbert Ltd being some of the first in the country[268]. One of the main changes this meant for "controlled" firms was they now became linked to an ever wider network of regional and national suppliers and customers, particularly for sub-contracting out work to help increase their outputs. For example, Daimler whilst manufacturing 12-inch H.E. shells for the Ministry directly, relied upon at least 17 different national firms for the original shell forgings which they then machined and despatched for filling or into storage[269].Another example is provided by the Ordnance Works who on the 14th July 1915, in response to a request from the Ministry of Munitions, sent a list of all of their sub-contractors who were then assisting them with the manufacture of their 4.5-inch field howitzers. This list included 104 firms supplying them material[270] and a further 64 firms who were machining for them.[271]

These lists included several motor and cycle firms (it is likely some of these were Coventry based), and those named included the Metropolitan Carriage Wagon Company, the London & North-Western Railway Company and also four other railway companies[272]. Considering the Ordnance Works was manufacturing a large range of munitions[273] this high number of 168 sub-contractors for just one of their contracts indicates the complex supply chain these "controlled establishments" were now embedded within. Additionally many of these national suppliers and customers were new to them and this suggests they could no longer rely upon only local firms for their needs. Effectively the demands of such firms like the Ordnance Works had gone beyond the capacity of local mid-war supplier firms. In turn this meant "controlled" firms were more externally orientated than in the early-war period.

[268] See Appendix for a complete list of all 'Controlled Establishments' in Coventry between 1915-1918 including the exact dates they were taken over and the trade group assigned to them.
[269] NA MN7/180 *'Shell Forgings up to June 30th 1918'*.
[270] Such items as various stampings, steel tubes, bolts, locks, castings, springs, screws, timber and leather items
[271] The included forging and pressing steel, making nuts, parts of mechanisms, screws and axletrees
[272] NA MUN5/373/1200/5 pp63-64. Unfortunately the original list supplied by the firm could not be located.
[273] See previous chapter 5 table 8.

The complex nature of how a "controlled establishment hub" firm may have appeared by the mid-war period is revealed in Figure 29 (overleaf). Here the Ordnance Works along with some of its known mid-war suppliers and customers are shown:

Figure 29: An Example of a Mid–War "Controlled Establishment Hub" Firm: Coventry Ordnance Works 1915 – 1916



Sources: NA MUN5/373/1200/5, Warren (1998) '*Steel, Ships and Men'*, Bacon (1940) '*From 1900 Onward'*, Frost (1920) *'Munitions of War'* and *Coventry Ordnance Works Brochures c1908 & c1910* CA PA1652/1-2

An associated feature with Coventry firms becoming "controlled establishments" was that some of them leant Chairman and Directors to work for the Ministry of Munitions. According to Hinton (1973) this resulted in the Ministry of Munitions being 'from first to last a businessman's organisation, intended to liberate the munitions industries from military direction, and the restrictions of established official routine, and to hand over the task of guiding and coordinating these developments to prominent businessmen familiar with industrial problems'[274]. It would seem this task was keenly taken up by many of the business leaders in Coventry with the following table 21 (overleaf) outlining some of the most significant recruited to work for the Ministry:

Table 21: Principal Ministry of Munitions Employees from Coventry or Associated Firms

Name of Ministry of Munitions Employee	Firm Representing	Positions held within the Ministry of Munitions and dates held (DD.MM.YYYY)
Anderson, D.M. C.B.E. 1920	Messrs. Cammell, Laird & Co. (Coventry Ordnance Works joint-owners)	Additional Gun Repair Section (01.02.1917); Deputy Director-General Gun Forgings (08.07.1917); Controller of Forgings, Stampings & Castings (23.02.1918 -16.12.1918)
Bacon, Vice-Admiral, Sir Reginald Hugh Spencer K.C.B. 1916 K.G.V.O. 1916 C.V.O. 1907 D.S.O.	Coventry Ordnance Works	Controller of Munitions Inventions (12.01.1918 - 31.03.1919); Ministry Representative on Committee on Awards for Inventions (16.06.1918)
Ellis, Sir Charles, K.C.B. 1917 G.B.E. 1919	Messrs. John Brown & Co. (Coventry Ordnance Works joint-owners)	Deputy Director-General (D), Munition Supply Department (19.07.1915); Director-General of Ordnance Supply (03.10.1916); Acting Member of Council A (--.11.1917); Head of Paris Establishment (13.12.1917); President of Commission Anglaise de l'Armament (--.12.1917); Liquidator of Contracts in France, Italy & Switzerland (1919)

[274] Hinton (1973) *The First Shop Stewards Movement* p29.

Herbert, Sir Alfred, K.B.E. 1917	Messrs. Alfred Herbert Ltd.	Head of Machine Tool Section at War Office under Sir Percy Girouard and Mr Booth (27.04.1915); Director of Machine Tools (03.06.1915); Deputy Director-General (14.08.1916); Controller (--.11.1917); transferred to Engine Branch Aeronautical Supply Department (23.03.1918 - 1919)
Iliffe, Edward, Mauger, C.B.E. 1918	Messrs, Iliffe & Sons, Ltd.	Machine Tool Department (07.07.1915); Assistant Controller (1917); (Controller (23.03.1918); Liquidator of Machine Tool Contracts (04.01.1919 - 30.06.1919)
Larke, W.J. C.B.E. 1920	British Thompson Houston Co. Ltd.	Labour Supply Department (--.06.1915); Director of Dilution and Allocation (08.01.1917); Special Service in connection with Demobilisation and Reconstruction (15.03.1918); Director-General of Raw Materials, Disposals Board (01.03.1919 onwards)
Martin, Percy	Birmingham Small Arms Co. & Daimler Co. Ltd.	Controller of Petrol Engine Supply and Member of Air Board (06.02.1917); Director-General of Mechanical Transport Supply and Petrol Engines (26.02.1917); Controller of Mechanical Transport Supply (16.05.1917 - --.01.1918)
Nicol, Sir T.D. K.B.E. 1920	Messrs Cammell, Laird & Co. (Coventry Ordnance Works joint-owners)	Finance Department (07.03.1917); Director of Mechanical Transport Contracts; Controller of Aircraft Contracts (01.11.1917); Chairman of Liquidation of Aircraft Contracts Committee (22.11.1918 - --.06.1920)
Charles Clarke	Smith's (Thomas) Stamping Works	Steels Committee of the Institution of Automobile Engineers & Chairman of Sub-Committee for Drop Forgings for Aircraft
Smith, Owen H.	British Thompson Houston Co. Ltd.	Controlled Establishments Division (21.06.1915); Assistant General Secretary (11.04.1916 - 31.10.1918)

Sources: H.M.S.O.(1920) *History of the Ministry of Munitions* Appendix VIII '*List of some of the principal officers'* pp260-275 & Muir (1958) p47

As table 21 highlights, many of the key positions within the Ministry, were in areas which reflect to some degree the types of armaments and munitions Coventry firms were tasked to produce. Therefore these firms were very well represented, at a national level, in machine tools, petrol engine supply, mechanical transport, gun repairing and gun forgings and also forgings, castings and stampings.

Through the Rugby & Coventry based firm of British Thompson Houston, its representative, W.J. Larke, was ideally placed within the Labour Supply and later Dilution and Labour Allocation Departments which of course were crucial to increasing munitions production from an engineering city such as Coventry. Towards the end of the war personnel such as Alfred Herbert, Percy Martin and Sir T.D. Nicol all became influential in the Air Board section, which the Ministry of Munitions absorbed by 1917. Indeed, Herbert & Martin were both heavily involved in aero-engines which by 1918 Coventry was manufacturing more of than any other British city. In relation to the mid-war cluster as a whole, what these Ministerial appointments meant was that some Coventry firms also had 'their finger on the industrial pulse'. One outcome of this is revealed in the following section where some Coventry firms were able to capture large orders for gauge making.

6.15 Gauge making in Coventry during wartime

Gauges[275] were something extremely vital to the armaments industry where inter-changeability of parts was already adopted by firms such as Birmingham Small Arms Company[276], following American practices. During wartime they were needed in ever increasing quantities due to the number of new firms now undertaking armaments production.[277] So important where gauges to war production, that a separate department was formed at the Ministry of Munitions on the 16th May 1916. At that time, it was known that the existing gauge manufacturers were working to the limit of their capacity. This Gauge Department therefore 'had to persuade a number of new firms to turn their energies to gauge making'.[278] Among some of these new firms were a number from Coventry, with the majority turning to gauge production for the first time. Table 22 (overleaf) summarizes some of these gauge contracts captured:

[275] For gauge definition see Chapter 5 page 91.
[276] Daimler's parent firm
[277] This was because they facilitated the dilution of labour with semi and low-skilled workers and were used to measure for accurate repetitious production in items such as guns, shells, fuses or any components thereof.
[278] H.M.S.O (1920) *History of the Ministry of Munitions* Vol. III, Pt.III, p15.

Table 22: Initial gauge contracts placed with Coventry firms 1915 – 1917

Company	Type of Gauge	Date of Contract	Initial Quantity Ordered	Price Per Gauge
Alfred Herbert Ltd.	Fuse 100 gauges	August 1915	50	£19.08 approx†
	Fuse 84 gauges	94/G/2258 date uncertain	Unknown	Unknown
Coventry Ordnance Works	Hardened Gauges	January 1916	1000s produced under	£4.5.0
		Contracts 94/G/1129, 94/G/1367 & 94/G/2316		
Coventry Gauge & Small Tool Co.	Unknown	7.1917	Unknown	Unknown
British Thompson Houston	18pdr. Shell 899C	21.10.1915	50	£2.10.4
Triumph Cycle Co. Ltd.	18pdr. Shell 617C	11.1915	50	£1.16.0*
	18pdr. Shell 617C	5.12.1915	200	£1.12.0
	18pdr. Shell 617C	23.1.1916	175	£1.12.0
Riley Engine Co. Ltd.	13pdr. Shell H.E. 689C	14.01.16	30	£0.8.9

Notes: † The total order for 50 complete sets was £954.12.11
* A Revision of Prices was carried out on the 01.10.15 and was for the lower price
Sources: NA MUN5/377/1390/1 & H.M.S.O. (1920) *History of the Ministry of Munitions* Vol.VIII, Pt.III Ch.1 Apx.2

The proceeding table notes the quantities given where the initial order quantity placed with each firm, however, these would have been added to by continuation contracts as firms became accustomed to gauge manufacture. The national figures give some indication of how busy Coventry gauge-making firms would have been after 1915.

The Gauge Department noted that nationally between August 1915 and December 1917, approximately 760,000 gauges, comprising 14,500 different types, were delivered by all national contractors for testing to the National Physical Laboratory[279]. The same table also reveals that Alfred Herbert Ltd. were the first local firm to receive gauge contracts, (just one month after becoming a "controlled establishment" in fact) this was due to them already making gauges, but only in a small way[280]. Following this firm's decision to develop and increase their gauge production, they were then in a position to accept 'large orders'[281]. Furthermore, difficulties in obtaining the American precision machinery necessary to produce fine limit gauges, led to the development of the home market, and Alfred Herbert Ltd. also 'gave help in this respect', by designing and building the necessary machines.[282] This shows that Alfred Herbert Ltd. would usually be one of the first firm's turned to when a new demand was being tasked of a British machine tool manufacturer.

In addition, the prices this firm received for these early gauge contracts appear significantly higher than later contracts given to other local or national firms. This is partly explained due to a downward tendency in prices for all munition contracts as the war progressed and also as firms became experienced with production they were able to tender a reduced price. Therefore being one of the first firms to capture any gauge contracts would usually prove highly lucrative. This early capture would have also been aided by having Alfred Herbert, assisted by Mr P.V. Vernon, Mr. Joseph Pickin (both Director's of his firm), and Edward Iliffe ('an old friend who usually acted as Chairman in my absence'[283]), positioned in the Machine Tool Department which before 1916 dealt with gauges.[284] This may have also aided other local firms too and suggests the Coventry mid-war cluster held a distinct local advantage in capturing contracts such as this.

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[279] NA MUN5/377/1390/1 This national figure does not include rifle gauges which were sent to Enfield, lock and gun gauges, as well as certain gun ammunition gauges, which were sent direct to Woolwich Arsenal.
[280] Davies (1983) *Social Relations, Herberts 1887-1922* p111.
[281] Ibid
[282] Ibid, p119.
[283] Herbert (1955) *Machine Tool Review* 'Memories 11' May-June p50. Iliffe taking up his appointed position on the 7th July 1915. See table 23 and the H.M.S.O. (1920) *History of the Ministry of Munitions* Appendix VIII *'List of some of the principal officers'* p268.
[284] Ibid Vol1.VIII Pt.II, p115.

Table 22 also notes that Coventry Ordnance produced thousands of hardened gauges. Although they cost more to make (£2.2.0 each unhardened, compared to C.O.W.'s £4.5.0 for hardened), these gauges would keep their accuracy for much longer. In fact when used it was found that hardened gauges would last three to four times longer than unhardened ones, thus justifying their additional cost. This meant that the Ordnance Work's gauge output was very important to the war effort as very few firms could undertake this hardening work due to them lacking 'the necessary experience'.[285] Fulfilling large gauge contracts was therefore one important new demand the mid-war state-anchored/centred cluster was able to successfully produce alongside its primary role of shell and fuse production.

Having now examined some of the additional ways in which the mid-war cluster was growing in complexity, both in form and the types of munitions it was being tasked to produce, it is important to reiterate that it was nevertheless a state-centred/anchored cluster which typified this mid-war period. The following section and table now summarizes the mid-war cluster.

6.16 Summary of the mid-war state-anchored/centred armaments and munitions cluster

Table 23: The Mid-War Cluster Spring 1915 to December 1915

- The main cluster type which characterized the mid-war phase of armaments and munitions production in Coventry was a state-anchored/centred cluster.
- This cluster centred on the dominant activities of an externally directed (by the Ministry of Munitions) local armaments committee (C.A.O.C.) and in particular this committee's Chairman, Engineer and Secretary who were key actors in the 'centring' of firms and the clusters activities.
- The Ministry of Munitions also 'centred' the cluster through direct investment into expanding munition firms and also upgrading the city's infrastructure.
- The cluster also showed high levels of labour in-migration which is to be expected in this cluster type.

[285] NA MUN5/377/1390/1 p25.

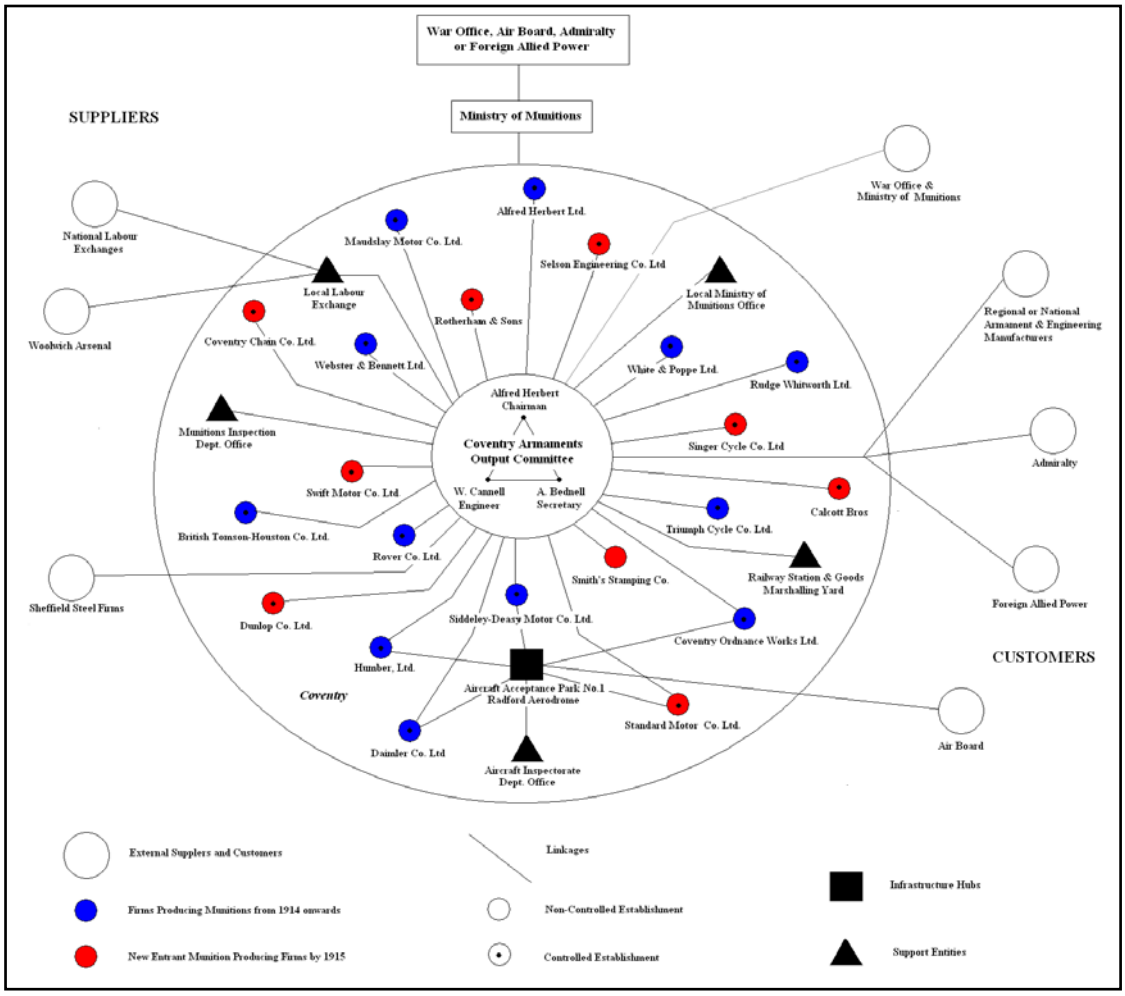
- The early war hub-and-spoke cluster persisted; however, it evolved through the creation of "infrastructural hubs".
- Key "hub" firms by the end of 1915 became "controlled establishments" and became linked to a multitude of new national suppliers and therefore where less locally and more nationally orientated

These last features reinforce Markusen's (1996) supposition that a state-anchored/centred cluster is more difficult to conceptualize as 'contingencies particular to the type of activity involved colour its operation and characteristics'[286]. In Coventry's mid-war cluster these contingencies included the rapid mobilisation and adaptation of the city's entire engineering sector, largely dictated by the dominant activities of the local armaments committee; heavy government investment into plant, machinery and infrastructure; new legislative powers in the form of "controlled establishment" orders placed upon key munition firms; rapid labour in-migration, and also an increasing diversity in the range of armaments and munitions tasked to manufacture.

The clearest way to summarize the mid war armaments and munitions cluster is in the form of a simplified state-anchored/centred cluster diagram overleaf:

[286] Markusen (1996) p306.

Figure 30: The Coventry State-Anchored/Centred Armaments and Munitions Cluster Spring 1915 to December 1915



Having now in the second part of this chapter analysed the mid war cluster, the third and final part will examine how this cluster evolved by the late-war period.

Part C: The Late War Cluster: January 1916 to November 1918
An Innovative Milieu

Before discussing what the late war cluster evolved into, it is appropriate to first outline how the mid-war state-anchored/centred cluster began to change.

6.17 The Coventry Armaments Output Committee (C.A.O.C.) – late war transformation

During the last two years of war the armaments committee's dominant role as the main non-profit entity to 'anchor' and organise engineering firms along co-operative lines had diminished. As early as 1916, it had transformed to become an entity which now placed entire contracts directly within the Coventry cluster with individual firms rather than sub-contracting the same contract across several. For example, by the beginning of 1917 it had in place direct contracts for weekly outputs of 1,500 4.5-inch high explosive (H.E.) shell (500 with Dunlop Rim & Wheel and the remaining 1,000 with Swift), 1,000 4.5-inch chemical shell (Rover), 2,000 2.75-inch H.E. shell (Coventry Premier), 500 18-pdr shell (Standard) and, according to the Ministry's official historian, perhaps the most valuable was a weekly output of a quarter of a million component parts, which Coventry possessed the national monopoly[287].

By the end of 1917 it was noted that various mid-war contractors had dropped out of contracts entered into either on co-operative lines or those directly placed by the C.A.O.C. This resulted in the weekly output of shells dropping to 500 4.5-inch H.E. (one third of the Jan 1917 output), 2,500 18-pdr shells (this quantity having increased, however only Standard was still making them in the Coventry area) and finally component part manufacture remained the same. This suggests it was from the autumn of 1915 until the beginning of 1917 when the Coventry cluster was producing its highest output of shells and after then many firms had switched munitions production.

[287] H.M.S.O. (1920) *Ministry of Munitions* Ch.X, Pt. II, Midlands p103 & MUN5/363/1121.24/4 pp14-26.

The Board of management of the C.A.O.C. stated this dwindling in numbers [of contractors] was 'greatly regretted' and in 1916 they had approached the Ministry with the suggestion to disband themselves. They pointed out that 'the contractors had now learnt their work and the Board had no longer scope for its powers'. This idea was opposed by a Sir James Stevenson[288] at the Ministry and the dwindling numbers were not seen as a poor reflection on the performance of the C.A.O.C. or its board of management. They felt merely the increasing tendency for Coventry contractors, 'to approach the Ministry direct, as their work had [grown] in importance, must be regarded as a natural development of the munitions situation in Coventry'[289].

In essence what had occurred was many Coventry contractors had initially tapped into the committees support network, (such as its managerial capability, labour organisation, adaptation and technical assistance), when first entering into shell, fuse or component production. Once firms were experienced in their manufacture and nearing the end of their initial contracts; and then the question of negotiating continuation contracts had arisen, usually the Ministry expected a drop in the contract price. However, the C.A.O.C. still wished to charge management fees upon those contracts, despite their services no longer being needed as fully as it was back in 1915. Naturally firms saw this as an added drain on their profits and attempted to circumnavigate the committee as a source for contracts and to deal directly with the various departments of the Ministry directly.[290] Coventry contractors had therefore exploited the benefits brought about by greater direct governmental involvement, through the C.A.O.C. working as an intermediary; however by 1917 firms were attempting to shake-off some of this control. They now wished for greater freedom from the apparatus which had been setup to help ease their entry into the armaments and munitions cluster during 1915.

According to the proceeding chapter, the late war cluster turned to war-winning weapons including: aero-engines, aeroplanes, tanks, machine guns and their associated component parts.

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[288] Who at this time was Director of Area Organisation at the Ministry of Munitions
[289] H.M.S.O. (1920) History *Ministry of Munitions* Chapter X, Pt. II, Midlands p103 emphasis added.
[290] For example the Trench Warfare Department, Mechanical Transport Department or the Air Ministry, which the Ministry of Munitions had absorbed by 1917.

From a purely militarist perspective it was these weapons which Britain and her allies were hoping could unlock the stalemate of trench warfare. From a business perspective Coventry firms also turned to these munitions as they would have been more lucrative; due to less firms nationally being able to undertake their more complex manufacture, when compared to fuses or shell cases. This meant local firms, particularly those connected with motor vehicles, were able to grapple back some of their bargaining power due to them possessing valuable pre-war experience in a closely associated trade (e.g. motor engines with aero-engines or motor body building with aeroplane fuselage manufacture).

Consequently by 1917/18 the larger firms in the cluster, although still "controlled establishments", were not acting in the same subservient role to the C.A.O.C. or the Ministry of Munitions as they were previously in 1915/16. In essence they wished for some of their autonomy back, and in so by doing, to enter into manufacture which might possibly leave them in a better post-war position, but at the same time they wished not to be seen as unpatriotic or profiteering. This late-war shift in the cluster is observed in the decreasing importance of the armaments committee who by the end of the war were no longer the dominant 'anchoring' entity it was during 1915. In addition to this decline, it seems new features emerged during the last two years of war which suggest that the Coventry armaments and munitions cluster not only continued to expand, but further increased in complexity. The first example of this was firms began to once again become more entrepreneurial and have one on eye on their future post-war position.

6.18 The re-emergence of the entrepreneurial firm

One example of a firm which began to consider its post-war position in the late-war cluster was that of Siddeley-Deasy. As discussed in the previous chapter this firm was heavily involved in aero-engine and aeroplane manufacture between 1915 and 1918[291]. However, during the end of this period, the firm's Managing Director John Davenport Siddeley (JDS) began to look at what market opportunities would present themselves when hostilities ceased, and to what types of cars to produce.

[291] See Chapter 5 tables 9 & 10

For this he looked to foreign deigns, and in particular to the United States of America. He decided to study the advances American motor technology had made in the three years since his firm, and the majority of the British motor industry, had produced a new car design. For this he decided to import a large and luxurious Marmon 5.5litre car through its British Delco agents[292]. With this car arriving during 1918, he was then able to divert some of his design staff to examine it piece by piece, with a view to turning out similar new designs in the post-war era. By this same time JDS had moved to Crackley Hall (now St Joseph's Convent School near Kenilworth), from Hill Orchard near Meriden. It was here described that "men sworn to secrecy were transferred to the private residence of JDS where they set up a design office in the billiard room"[293] although the Marmon was probably dismantled quietly at the Parkside factory. This was due to the Ministry having strict controls on non-essential work. Considering at this time the firm was still a "controlled establishment" which was entrusted with much experimental aeronautical work[294], and also the firm having recruited some of the best design staff from Farnborough[295], meant that the examination had to be done in secret. This example demonstrates one of the ways in which a Coventry firm was starting to contest the mid-war state-anchored/centred cluster.

Other examples included Rover who were considered guilty in considering their post-war automobile policy above national interests as by the end of the war[296] and Triumph who were accused of utilising war-time government investment for post-war advantage.[297]

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[292] Smith (2006) *Armstrong Siddeley Motors* Ch.4 p69

[293] Armstrong Siddeley (1956) *The Evening and the Morning* Note: According to Smith (2006) p69 JDS's Grandson, Ernest Siddeley, suggested this work was never carried out in the billiard room, however, the works journal of Siddeley-Deasy, *The Employee's Quarterly* shows a large billiard room for its workers and perhaps this work could have been done there at the Parkside factory.

[294] For example the re-design of the Beardmore Halford Pullinger B.H.P. engine, which later became the Siddeley Puma.

[295] Including, Major FM Green as Chief Engineer (who had worked for Daimler up to 1910), John Lloyd, Head of Stress and S D Heron an engine designer. See *Flight* 13th July 1933 p705

[296] NA MUN5/363/1121.24/4 p19 The situation got worse when the Ministry approached the firm in March 1917 for a repeat contract to make 4.5-inch SK lachrymatory shell. Rover flatly refused stating 'its resources were taxed to the utmost on other government work and refused to continue manufacture of the lachrymatory shell'. In fact, according to Morewood (1992), Rover's management were already finding time to consider manufacturing cars once again

[297] Ibid, MUN5/363/1121.24/4 pp22-23

As already discussed in section 6.17, the role of the dominant 'anchoring' entity (the C.A.O.C.) had changed by the war's end and in addition this section has demonstrated that it was also the willingness of firms themselves which had changed. Alongside these changes Chapter 5 also outlined the cluster was still continuing to expand, albeit at a slower rate, by the wars culmination. It is to account for some of this continued growth that the following section now addresses.

6.19 Recapping the main features of an innovative milieu

Before the late-war cluster is discussed in relation to the innovative milieu concept, it is useful to firstly define and outline its key features. According to the research body GREMI, who originally developed this concept, an innovative milieu may be defined as:

> The set, or the complex network of mainly informal social relationships on a limited geographical area [therefore they are set within a cluster], often determining a specific external 'image' and a specific internal 'representation' and a sense of belonging, which enhance the local innovative capability through synergetic and collective learning processes.[298]

According to chapter two, table 1 there appeared three main features which constituted an innovative milieu summarized below:

Table 24: The three main features of an Innovative Milieu

1. Effective actor relationships within a regional or local cluster
2. Social contacts that enhance learning processes
3. An image or sense of belonging

Note: See Chapter 2 pp22-23 for a greater discussion on the innovative milieu concept.

With the above features in mind the central role the late-war cluster played in developing and manufacturing innovative aero-engines shall now be discussed.

[298] Camagni (1991) p3.

6.20 The development of the Bentley rotary aero engines through an innovative milieu

Already an established motor engineer Lieutenant W.O. Bentley, Royal Naval Air Service, was instructed by a Commander Briggs at the Admiralty to study the overheating problems in rotary aero-engines in late 1914. Based on his pre-war racing experience in the application of aluminium-alloy pistons in cylinders he redesigned the Clerget aero-engine with the assistance of Gwynnes in Chiswick. This became termed the Admiralty Rotary 1 (AR1)[299]. However it would seem both Bentley and Gwynnes did not see eye-to-eye when he wished to further improve this engine and what he really wished was to design a rotary engine of his own design incorporating all he had learned with the AR1 and from his pre-war motor racing experience. Briggs, accepting that a Bentley-designed aero engine had huge potential for aiding the war effort, carefully researched the firms which would be best suited to design, test and manufacture such an engine. In Briggs's own words:

> You're to take your bags to Coventry, Bentley…Humbers have got all the facilities you'll want. They're only churning out Army bicycles – thousands and thousands of them – and terrible things like travelling kitchens. I think they're rather offended that they haven't been given something more challenging to test their mettle, so they'll welcome you with open arms.[300]

Upon arriving at Humbers in 1916 Bentley found Brigg's assessment to be correct and that the firm was bored stiff with the commonplace trivialities on their production lines[301]. Bentley's pleasure at being assigned to this firm can be imagined as he held a particular respect for this motor manufacturer as he had faced them in racing competitions before the war. Additionally he held personal friendships with some of the key personnel he was later to work closely with.

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[299] Gunston (1995) *World Encyclopaedia of Aero Engines* p23
[300] Bentley (1958) *W.O. The Autobiography of W.O. Bentley* Chapter 5 p83.
[301] This friction between the firm and the Ministry is backed up by the Chairman of Humber, Mr Powell, who when visiting the Ministry on the 27th Jan 1916 to discuss the 4.5-inch howitzer shells the firm were also producing, is described as saying 'that he would rather go his own way, and if the Government would allow him to manufacture motorcars he would much prefer it'. See NA MUN7/182.

First there was a F.T. Burgess, his 1914 TT rival; second there was Niblett, the Works Manager, and his assistant M.J.F. Crundle, who had ridden motorcycles for Humber and was now Chief Tester, and finally a Mr S.Wright, in charge of the fitting shop, who had been an acknowledged Humber driver also. It would seem Bentley was therefore well placed by the Admiralty into the perfect environment in which to perfect his design ideas. On the one hand he had at his disposal a large firm with an underused design, testing and manufacturing capabilities, and on the other, the staff there to assist him were either personal friends and/or came from a similar background to him in motor racing[302]. This common ground and personal friendships helped to engender a high degree of mutual trust as Bentley would have been easily accepted into the Humber design team and his ideas and previous experienced not unduly challenged. This is an example of social contacts that enhanced learning process as outlined in feature 2 table 24 of the innovative milieu.

Having set to work during 1916 in this environment Bentley and Humber's design team proceeded to incorporate all the ideas he wished to implement at Gwynnes. What was produced was an engine fitted with aluminium cylinders with cast iron liners, and aluminium pistons and also dual ignition to improvement reliability[303]. This resulted in a new 1,055 cu in capacity engine which improved on the 130bhp Clerget he had developed with Gwynnes (AR1) and this time gave 150bhp and was termed the Bentley Rotary 1 (BR1)[304]. The work this involved is described in the *Encyclopaedia of Aero Engines* as 'a complete redesign of the cylinder, with an aluminium barrel, cast-iron liner and steel head tied to the crankcase by four long bolts, with two valves operated by push rods'[305]. This is believed to have been the first ever production air-cooled cylinder with an aluminium barrel.

Another important development with Humber's assistance was the BR1 was made considerably easier to manufacture and cost just £605 per engine, compared to £907 per AR1 engine at Gwynnes[306].

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[302] Bobbitt (2003) *W.O. Bentley The Man Behind The Marque*, Chapter 3 p97 and Bentley (1958) p84.
[303] Gunston (1995)
[304] Ibid, Bobbitt (2003) p98.
[305] Ibid, Gunston (1995) p23
[306] Gunston (1999) *The Development of Piston Engines*

Incorporated into the design of the BR1 was the important part that other Coventry firms played in being able to perfect the widespread use of aluminium-alloys. According to the proceeding chapter, between December 1915 and November 1918 the number of metal working firms, inclusive to the cluster, had nearly trebled and this was partly due to the increasing need of aluminium alloys in aero-engines such as the BR1[307]. One local firm that Bentley and Humber turned to was Rowland Hill & Sons. This was an old established company who claimed to have the largest general experience in the production of motor castings as they had produced many of the cylinder and crankcase castings for the original Daimler cars at the turn of the century[308]. In a joint research venture with this firm Bentley was able to perfect the use of very high quality aluminium alloys which was so successful to this engines reliability and high power-to-weight ratio.

In describing the new high quality working practices which had to be devised in order to manufacture these alloys, Rowland Hill's metal-mixing department had to accurately weigh all the various alloys to be used and these where then sent:

> ...onto the foundries in complete charges ready for the furnaces. This work is very carefully done and checked so as to avoid any possibly of error in the composition of the alloys. In addition, many mechanical and chemical tests are carried out daily to ensure uniform high quality… All consignments of metal received by the firm are thoroughly tested and analysed before being passed through to the stores to ensure that no material faulty in any respect shall be used.[309]

This suggests the presence of feature 1 in table 24 in that spatial proximity promoting frequent face-face contact, between the designer and innovator (Bentley and his design and testing staff at Humber) with the manufacturer (the Works Manager and his staff at Humber) and then finally with a key local supplier (Rowland Hill & Sons),was facilitated within this later-war innovative milieu cluster.

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[307] Other reasons included munitions were needed in ever increasing quantities and manufacturers turned to drop-forging, stamping, forging and pressing firms to a greater degree than they had done so previously.
[308] *Coventry and its Industries Official Handbook* (1918) p64.
[309] Ibid, p64.

It also demonstrates the key actors involved were coming from different organisations and backgrounds and combined within this innovative milieu a collection of ideas and experience which had not before previously been associated. These ideas included:

- W.O. Bentley providing new ideas from his previous motor-racing and aero-engine experience. He further added an air of authority and decision-making as he was put in charge of this development program and was still a commissioned officer under the Admiralty's direction. This also addressed the need for accountability.
- Humber's staff provided their motor racing, motor vehicle and munitions design and manufacturing experience. They also provided a design office, testing facilities and manufacturing capabilities.
- Rowland Hill & Sons provided metallurgical expertise and also the benefit of their strict quality standards. This was crucial when considering these aero-engines were using aluminium parts with very fine limits of tolerance and also this metal was not in widespread use in engineering to any great extent before the war.

It was the coming together of these actors in space (the Coventry armaments and munitions cluster) and time (between 1916 and 1918) which produced these innovative rotary aero-engines. This was through the actors successfully combining complementary capabilities from differing fields of activity.
These design ideas and experience were then formulised into new innovations, such as the aluminium barrel within the cylinder. These were then tested and perfected within the innovative milieu setting ultimately leading to the BR1 being approved to be manufactured in quantity in the late-war cluster.

Figure 31: A BR2 rotary engine on a test bed likely taken at Humber's factory

Note: W.O. Bentley standing in the centre with what appears the inspector to the left possibly Sammy Davies of the A.I.D.
Source: Smith & Fry (1997) *Godiva's Heritage. Coventry's Industry*

During the course of this process Bentley also designed a completely new and larger 1,522cu in capacity engine which he hoped would attain over 200hp. With the success of the BR1 engine proved, clearance was given to proceed with this larger BR2 engine (Figure 31) and the transition was eased as many of the parts were interchangeable. Three prototypes were ordered in April 1917 and by October it was ready to test in Coventry in front of the local Aircraft Inspectorate Department (A.I.D.) Admiralty Inspector S.C.H. 'Sammy' Davis. Davis was yet another motor racing friend of Bentley's and also held long standing ties with Daimler[310]. In front of him and the A.I.D. the BR2 engine produced 234hp and proved an instant success[311].

[310] This again suggests Bentley was fortunate within the late-war cluster as he was surrounded not only at Humber's, but also with the local A.I.D. by an 'old boys' network' of motor racing friends which eased his and his engines acceptance through a high degree of mutual trust. This is typical feature for an innovative milieu according to Chapter 2. Many of these same gentlemen would form the nucleus of what

According to Bentley during 1918, when the widespread manufacture of this BR2 engine was being adopted, this all became too big for Humbers to cope with and so he had to relocate his headquarters to the Daimler factory. Here he was able to jointly co-ordinate the huge construction programme then being instigated which involved Daimler, Humber and Crossleys and amounted nationally to 30,000 engines[312]. What resulted from this relocation was that the final product of the innovative milieu (the BR2 aero engine), upon needing to be manufactured in quantity, could now be seamlessly accomplished within the more entrepreneurial and experienced late-war armaments and munitions cluster (as discussed in sections 6.18 and 6.23). This meant that the late-war cluster and some of the leading firms within it were now operating at the peak of their wartime efficiency. This is demonstrated by returning to the BR2 story below.

Daimler's war history noted that they were put in charge of this BR2 engine program and this was a new form of decentralised technical control implemented by the Air Ministry. They suggested that:

> At the request of other firms the Daimler Company undertook the preparation and issuing of drawings from their own Drawing Office. Their chief engineer, [A.E. Berrimen], was made honorary Engineer-in-Charge of the project. An engineering conference was established under his Chairmanship and at these meetings all technical difficulties were not only discussed but settled authoritatively…In this way it was possible to perform efficiently, under difficult circumstances, the true function of technical engineering.[313]

This was in marked contrast to Daimler's previous aero-engine programs, where their production had to be dealt with by a centralised authority – the Air Ministry.

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became known after the war as 'The Bentley Boys' when racing at Le Mans in cars made by Bentley Motors, Cricklewood, London.

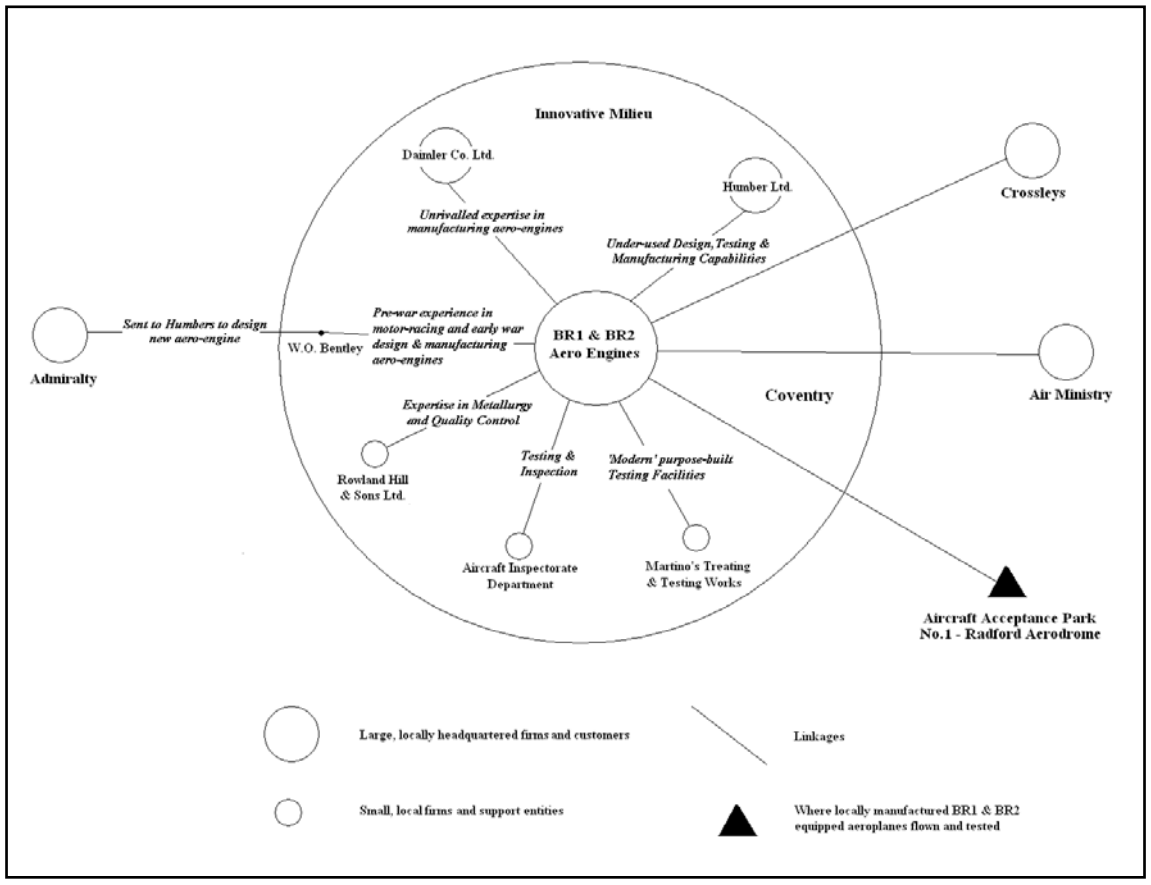
[311] Ibid, Gunston (1995) p23.

[312] Ibid, Bobbitt (2003) p101

[313] Ibid, Frost (1920) p161

This governmental/contractor relationship usually resulted in potential delays and confusion and it must have been with delight that Daimler was finally allowed the freedom as the leading British aero-engine contractor to manage this program without undue Ministry interference. So successful was this new system that production began in early spring 1918 and by the summer output was already around 120 engines per week[314]. This then was the innovative environment which characterised the late-war Coventry cluster. Innovative agents, such as Bentley, were sent to the city in order to successfully implement their wartime ideas and experience into useful designs. Once there, from 1916 onwards, he was able to tap into the design expertise of firms (Humbers); the aero-engine production experience of other firms (Daimler), and further undertake collaborative research to overcome any technical problems that ensued (Rowland Hill & Sons). This is now summarized below:

Figure 32: The Coventry Innovative Milieu through the design and manufacture of Bentley aero engines 1916-1918



[314] Ibid, Bentley (1958) p87.

With the cluster having embraced all manner of wartime products, particularly during the mid-war period onwards, this gave Coventry manufacturers a distinct expertise in being able to readily adapt to any new innovation it was either tasked to help design or manufacture. One successful armament and munition which was designed and produced in quantity has now been discussed namely that of the late-war design and manufacture of Bentley rotary aero-engines[315]. When compared to the 80h.p. Gnome rotary aero-engine built by Daimler in the early-war cluster (see Chapter 6 section A) then the progress in design that the BR2 represented can be seen. The Gnome weighed 3.26lbs per B.H.P. it produced, whereas the BR2 weighed only 2.165lbs per B.H.P. it produced. This was a power-weight ratio improvement in only 2-3 years of 30 percent[316].

In terms of what these Bentley rotaries meant to the war effort they are now largely credited, when fitted to the Sopwith Camel, as winning back air superiority during 1917/18 from the Imperial German Army Air Service. Furthermore, the Sopwith Camel is credited with shooting down 1,294 enemy aircraft, more than any other aeroplane type during the war[317]. A feat not possible without the light, powerful and reliable BR1 aero-engine. The very fact that its larger brother, the BR2, is still considered the pinnacle of rotary engine development, and that it saw active RAF service until 1926, is testament to the success of the late-war Coventry cluster as an innovative milieu[318]. This late war cluster is now summarized below:

[315] There are also other examples such as the development required to perfect the tank or incendiary bullets needed to defeat the Zeppelin menace both of which were engineering problems solved within an innovative Coventry munitions cluster
[316] *Flight* 7th August 1919 p1051 Another significant improvement was the reliability in British aero engines.
[317] *Flight* 22nd April 1955
[318] Ibid, Gunston (1995) p24.

6.21 Summary of the late-war armaments and munitions cluster

Table 25: The Late-War Cluster January 1916 to November 1918

- It would appear that no singular cluster form typified this later-war period.
- The mid-war importance of the Coventry Armaments Output Committee as the dominant 'centring' entity had diminished.
- Some firms such as Siddeley-Deasy, Rover and Triumph began to re-assert their entrepreneurialism and contest the mid-war state-centred/anchored cluster due to now having one eye on their post-war positions.
- Some of the later war growth (as identified in the proceeding chapter) can be accounted for by new entrant firms acting as 'branch plants' such as Conner & Hotchkiss. This suggests that the late-war cluster contained elements of a satellite platform cluster, however these firms were exceptions.
- The most distinct shift in the cluster was towards research and development and innovation and three examples were given:
  i) The emergence of dedicated research and development establishments.
  ii) Through a 'learning by doing' process some firms, such as Daimler, were able to take a leading role in the development and manufacturing of aero-engines.
  iii) Collaborative innovation, such as in the design and manufacture of the Bentley rotary aero-engines, was now possible within a successful late-war armaments and munitions cluster. This was realised through an innovative milieu that was open to outsiders and facilitated the coming together of innovative agents with firms with distinct, however, complementary knowledge and with the Admiralty and the Air Ministry to tackle new engineering challenges both in design and manufacturing.

Having now analysed Coventry's early, mid and late-war armaments and munitions cluster in relation to the conceptual framework the next section wishes to summarize the contribution of this chapter.

6.22 Summarizing the contribution of the conceptual framework when applied to this armaments and munitions cluster

This chapter identified and explained what type of cluster(s) Coventry's armaments and munitions sector became during the First World War. It began by examining the early war cluster centred upon vehicular transport (identified in chapter 5) and found this took the form of a nucleated hub-and-spoke model which had a strong local trade association presence. As the war dragged on into 1915 this led to the setting up of the Ministry of Munitions (M.O.M.) and consequently of a local Coventry Armaments Output Committee (C.A.O.C.) shortly thereafter, which in turn made a greater number of Coventry firms switch to producing shells, fuses and component parts.

This chapter was able to account for this evolution as by December 1915 the mid-war armaments and munitions cluster was seen to be mainly state-anchored and centred. This anchoring or 'centring' was achieved locally through the activities of the C.A.O.C's Chairman, Engineer and Secretary and externally through large M.O.M. inward investment. To meet this shift and expansion the mid-war cluster also began to attract high labour in-migration particularly semi-skilled female machine operators. Further complications to this mid-war cluster were discussed including the persistence and evolution of the early war hub-and-spoke model whereby "infrastructural hubs" were created and that many key "hub" firms also became "controlled establishments" whereby the Ministry of Munitions exercised an even tighter control of their workforce and munitions production. The chapter revealed that these same "controlled establishments" became more nationally orientated through forming linkages with an ever greater variety of non-local suppliers. By the late period, Chapter 5 suggested the cluster continued to expand and turned to manufacturing war winning weapons such as aeroplanes and aero-engines in large quantities.

This chapter demonstrated this was due to the Coventry armaments and munitions cluster continuing to evolve, however, no longer did one singular cluster model typify this late-war period as it had done in the early and mid-war periods.

By 1917 the importance of the Armaments Committee had diminished and its role changed and also some of the leading firms began to reassert their entrepreneurialism and contest the mid-war state-centred/anchored cluster due to them having one eye on their post-war prosperity. Additionally it was shown that some of the late-war growth could be accounted for by new entrant firms setting up 'branch plants' where they had minimal interaction with other munition firms within the cluster and were mainly externally controlled and orientated. This suggested that elements of a satellite platform cluster were emerging towards to the end of the war, but these firms were few in number. The most visible shift in the late war cluster was the moving away from manufacturing shells, fuses and component parts towards many new and existing firms concentrating on aeroplane and aero-engine manufacture.

The chapter revealed this was achieved by the cluster becoming an environment for innovation and research and development. Three ways this manifested itself were: the setting up of local dedicated engineering research and development establishments; through a 'learning by doing' process firms such as Daimler were able to gain the confidence to develop and take on the manufacture of more complex aero-engines and to manufacture them in greater quantities, and lastly and perhaps the most important of all was under direction of the Admiralty and Air Ministry the cluster became a innovative milieu or environment which fostered and nurtured the coming together of outsiders, innovative agents and firms with distinct , however, complementary knowledge in order to overcome engineering challenges in the design and manufacture of new aero-engines.

The evolution of Coventry's armaments and munitions cluster between 1914 and 1918 is summarized overleaf:

Table 26: The Changing Nature of Coventry's First World War Armaments and Munitions Cluster

	Early War Period	Mid-War Period	Late-War Period
Number of Firms & Support Institutions/ Infrastructure	30	98	150
Main Armaments & Munitions Being Produced	Vehicular Transport	Shells, Fuses & Component Parts	Aeroplanes, Aero-engines, Tanks & Machine Guns
Dominant Cluster Model	Nucleated Hub-and-Spoke	State Anchored/Centred	No singular model, however elements of: Contested State Anchored/Centred, Satellite Platform, & Innovative Milieu[319]

Having now analysed and explained the changing nature of Coventry's 1914-18 armaments and munitions cluster the next chapter shall conclude the research and make recommendations.

[319] Please note due to space restrictions a detailed examination of all three types could not be given, but two firms which exhibited many of the features associated with branches within a satellite platform cluster were Conner Magneto & Ignition and Hotchkiss et Cie.

Chapter 7: Conclusions and Recommendations

The previous chapter identified the types of industrial clustering exhibited by the armaments and munitions sector in Coventry between 1914 and 1918. This chapter now wishes to summarize the research findings and also consider some of the implications of this wartime cluster to the development of the city in the first quarter of the twentieth century. The chapter begins by reflecting upon the aim and objectives (Chapter 1) and how the study has addressed these. Following this, the cluster's overall contribution to the war effort is summarized and the types of cluster it became at the beginning, middle and late-war periods. Thirdly, considering these implications the next section outlines some of the positive and negative legacies this cluster left upon the city. Lastly, the chapter finishes by evaluating the conceptual framework and the methodological technique used and suggests directions for future research.

The main aim of the study was:

- To examine the historical geography of Coventry's armament and munitions cluster between 1914 and 1918.

In order to accomplish this aim the study was concerned with completing four objectives:

- To identify the principal characteristics of the companies manufacturing armaments and munitions between 1914 and 1918.
- To map the changing distribution of these firms across Coventry between 1914 and 1918.
- To examine some of the linkages between these firms to establish the type(s) of armament and munitions cluster(s) evident in the city at this time.
- To develop an explanation as to why a successful First World War armaments cluster developed in Coventry and add to a broader understanding of the economic, industrial and urban development of the city in the first quarter of the twentieth century.

The research has highlighted the continued importance of theorising industrial clusters, with particular attention being paid to Markusen's industrial district/cluster typology (Chapter 2). The usefulness of a complementary extensive and intensive research method to study a wartime cluster was also documented (Chapter 3). The identification and mapping of Coventry's First World War armaments and munitions cluster provided an important case study of an industrial cluster successfully undergoing rapid change brought on by the pressures of wartime (Chapters 5). Lastly, by relating the conceptual framework in Chapter 2, and to examine some of the linkages between firms, the research findings highlighted what type(s) of cluster Coventry's First World War armaments and munitions cluster was and further accounted for how growth and evolution was accomplished (Chapter 6).

This now allows for a number of conclusions to be drawn from this study:

7.1 Armaments and Munitions Production

Coventry's contribution to war production was significant with it being transformed into an arsenal of war for four-and-a-half years which led to three Royal visits. An enormous variety of munitions production was undertaken ranging from: tiny jewels used in instruments and torpedoes produced by Lee F. & Company, to the largest 100-ton 15-inch naval guns produced at the Ordnance Works.The scale of production is evident from the Navy and Army, through the War Department, spending £40,500,000 in Coventry during the war, or in 2007 prices over £1.3 billion[320]. By the end of the war the White & Poppe managed National Fuse and Filling Factory recorded 19,940,000 fuses, 9,880,000 gaines and 31,060,000 detonators being filled. Additionally 13 million fuse-bodies, 6 million fuse-holders and shell sockets were manufactured on the same site and nearly 4,000 subsidy engines for Hallford and Dennis Brothers lorries from their Drake Street factory[321].

[320] Wilkins (1919) *Celebration of Peace* For the price conversion see Officer, L.H (2008) *Measuring Worth: Purchasing Power of British Pounds from 1264 to 2007.* See bibliography web-based sources. Note: It is not clear if this figure includes all money spent through the Ministry of Munitions.
[321] The Limit (1918-1921) *W & P War History* and Hassell (2003) p21.

It was not just in production output which the Coventry cluster excelled, but arguably more important was its contribution towards British engineering in the form of designing and manufacturing engines, driveshafts, gearboxes and tracks for the first tanks. Additionally it was Coventry firms which perfected the design of some of the most significant British aero-engines during the war such as the Bentley Rotary 1 and 2 and the redesign of the Beardmore-Halford-Pullinger which became the Siddeley-Deasy Puma. The cluster also became the leading centre for the fledgling British aeronautical industry which resulted in the city producing 25 percent of all aeroplanes and aero-engines manufactured by Great Britain during the war[322].

Chapter 5 identified their appeared three main phases to this armaments and munitions production in Coventry between 1914 and 1918:

- The early-war period was dominated by vehicular transport requisition, conversion and manufacture which isn't surprising considering Chapter 4 highlighted the city was at the forefront of motor vehicle manufacture in Britain before hostilities began.
- By the mid-war period many existing and some new entrant firms switched to producing huge quantities of shells, fuses and component parts in response to the 'Shells Crisis'.
- After 1916 the cluster once again adapted, but this time towards designing and manufacturing war-winning weapons such as tanks, machine guns, aeroplanes and aero-engines.

The study also revealed that the area this cluster was spread over more than tripled in size from 4 square miles in 1914 to around 13 square miles by 1918.

[322] H.M.S.O. (1920) *History of the Ministry of Munitions* and Dewar (1921). In total the research was able to calculate 6,518 aeroplanes and 12,718 aero-engines were produced in the city during the war. This figure may have been even higher when spare and disassembled engines are taken into consideration.

Within this, there comprised no less than 137 firms (based in 166 factories) supported by 13 key support institutions and infrastructure by the cessation of hostilities, but it may have been as large as 200-300 firms[323]. The firms' themselves ranged from the house-hold watchmakers of Joseph White & Sons working in a tiny shed-like munitions workshop with 3 workers to the massive 141.5 acre site of the National Fuse and Filling Factory employing 12,000 workers[324]. Resulting from the unprecedented levels of employment and the rate of expansion the population of the city rose from 118,000 to 133,000 through the rapid in-migration from all parts of Britain of munition workers to serve this cluster. The total number of workers involved in producing munitions was estimated at 60,000 with 16,000 commuting in daily from Birmingham, Leamington, Warwick, Rugby, Bedworth, Nuneaton and Atherstone amongst other places[325]

By relating the conceptual framework developed in Chapter 2 the study identified three main cluster types were evident at each of these periods:

<u>The Early War Cluster – August to December 1914</u>

- This was typified by a nucleated hub-and-spoke cluster comprising 25 firms taking the form of a series of 'hub' firms situated within, or 'spoking' out to, a concentration of smaller local supplier firms.

In relation to conceptualising the early war cluster as a nucleated hub-and-spoke cluster this suggested reasons as to why as many as 25 firms immediately entered into armaments and munitions production by December 1914. Using the example of Daimler, Chapter 6 suggested these included: financial security; linkages to its parent firm B.S.A., including the diffusion of engineering practices such as perfecting repetitious production; and also being able to rely upon external firms for successful knowledge and/or technological acquisition.

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[323] Nowell (1927) gave this as over 200 firms. Churchill stated in Parliament during the 1918 Embargo strike it was c.400 firms and Spennell's 1919/20 Coventry Directory listed c.330 engineering firms present within the city c.1918/19 when the city would have been surveyed - see Annex 1 for this list. Suffice to say the figure of 200-300 is a conservative estimate.
[324] C.A. Building Plan 8280 5th June 1916 and Hassell (2003) p20.
[325] Nowell (1927); Bryant (1987) Chapter III p70; Carr (1978) p56, and Lancaster (1987) *"Who's a Real Coventry Kid?"* p65.

Finally being situated within a web of linkages to smaller supplier firms suggested one more reason as to why the early war cluster took the form it did – namely these firms, through being heavily dependent upon the 'hub' firm, were also enticed into the early war cluster. One important departure from Markusen's (1996) hub-and-spoke model was this early war cluster possessed a stronger local trade association presence that was also 'hub' firm led. It would appear it was therefore a combination of all of these factors which enabled Coventry firms to rapidly form a successful armaments and munitions cluster by December 1914.

The Mid-War Cluster - Spring to December 1915

- The main cluster form which typified the mid-war period was that of a state-anchored/centred cluster, 'centred' on the dominant activities of the Coventry Armaments Output Committee.

With regard to conceptualising the mid-war cluster as a state-anchored/centred cluster this suggested reasons why 63 more firms successfully adapted and entered into armaments and munitions production through the course of 1915. The most important entity which allowed this to happen was the Coventry Armaments Output Committee. Chapter 6 demonstrated how it was particularly this committee's Chairman (Alfred Herbert), Engineer (Mr Cannell) and Secretary (Alfred Bednell) who were central to: securing the contracts with the Ministry of Munitions; organising and educating the city's many varied engineering firms, and adapting their manufacturing capabilities towards shell and fuse production. The same chapter also showed it was Alfred Bednell who was at the centre of forming the linkages between the firms, the committee and the state (in this instance the Ministry of Munitions), through informal business networks formed through a private social club.

Chapter 6 continued with an examination of the provision of capital for firms and the cluster in order to facilitate this adaptation and expansion.

It was noted than mainly "controlled" firms were the recipients of many thousands of pounds of investment, however, firms taking on contracts through the armaments committee tended to have to use their own capital reserves or fund this through issuing more shares. At the same time, the Ministry also began to increase the city's power infrastructure and it was noted by 1918 its capacity had more than doubled. There was also significant investment put into new permanent housing, and temporary accommodation such as colonies of hostels and 'munition' and 'colony' cottages. A further feature, which increased the complexity of the mid-war cluster, was the building of new infrastructure that became 'hubs' or focal points of activity such as Radford Aerodrome. Another was that many of the leading firms became directly "controlled" by the Ministry of Munitions and this meant they became more externally orientated towards a wider network of regional and national suppliers and customers.

These many reasons taken together suggest how at the local level the Ministry of Munitions successfully and rapidly transformed the 1914 nucleated hub-and-spoke cluster into a state-anchored/centred cluster. They also reveal just how important local governance systems were to achieving this – namely the Coventry Armaments Output Committee operating through informal channels – the Coventry & County Club.

The Late-War Cluster – January 1916 to November 1918

- The study found that no singular cluster form typified the late-war period. Despite this the cluster can be best interpreted as a territory or innovative milieu in which innovation was facilitated and encouraged.

By the end of the war the study revealed the cluster had grown once again by an addition of 52 firms, but was also continuing to increase in complexity. Firstly the dominant role of the Coventry Armaments Output Committee diminished and some firms were reasserting their entrepreneurialism and contesting the state-anchored /centred cluster, setup to help encourage their entry during the mid-war period.

Furthermore some of the late-war growth was attributed to new entrants acting as "branch plants" forming elements of a satellite platform cluster to emerge. Despite these changes the most distinct shift was a cluster which became a territory for research and development leading to innovation for war winning weapons. Three ways the cluster responded to meet this need were: first new research and development establishments were built; second firms gained in confidence as the war progressed through a 'learning by doing' process leading to innovation; and third and perhaps most important, the cluster had partly evolved into an innovative milieu that facilitated collaborative innovation in both design and manufacturing between innovative agents, firms and the Admiralty or the Air Ministry.

These many reasons taken together suggest how and why into the late-war period the city was able to maintain a thriving armaments and munitions cluster, despite particularly much of its shell and fuse work being switched to a series national factories built for such a purpose. It was therefore due to Coventry firms being highly adaptive and receptive to change and the cluster and city as a whole remaining open to further new entrant firms and the expansion of existing ones. This undiminished willingness to take on new engineering challenges resulted in the cluster being at the forefront of a new British aeronautical industry and is even more remarkable when not a single Coventry firm was manufacturing aeroplanes or aero-engines before hostilities began[326].

Having described the forms that this cluster took at three key periods this realises objective three of the study. Considering the implications of Coventry's wartime armaments and munitions cluster, the next section outlines some of the short and long-term implications, both positive and negative, this had upon the economic development of the city during the first quarter of the twentieth century.

[326] The Humber Motor Co. Ltd. before the war attempted to manufacture aeroplanes, but this they stopped in 1912 due to unprofitability. Coventry Ordnance and the Victor Moto Company were two other firms who experimented with aeroplanes pre-war, but only Humber tried to produce them on any kind of commercial basis.

7.2 The legacy of Coventry's WWI armaments and munitions cluster

Positive Effects

As a result of the First World War new industries emerged within city such as the aeronautical industry with Daimler producing over 8,000 aero-engines, more than any other firm in the world at that time.[327] Similarly the cluster became a centre for electrical engineering in the form of high-tension magnetos where from a pre-war position of importing nearly all Magnetos from Germany, to a wartime one where 36,730 were being produced by B.T.H., with a further 20,000 on order, and 50,000 manufactured by M-L Magnetos.[328] Both of these new sectors helped to diversify Coventry's motor vehicle centred engineering base and helped to counteract a continued decline in textiles and watchmaking.
This suggests certain local firms were, as a result of this successful cluster, propelled to the forefront of new embryonic industries associated with Britain's second industrial wave.

Existing sectors such as stamping, drop-forging and foundry firms also received a considerable wartime boost. For example Mr Bernard Brett, of Brett's Patent Lifter Company writing in 1918 suggested 'It is probably correct to state that the War has brought out the possibilities of drop forging more than anything else, as parts have now been made by thousands instead of tens.'[329] Machine tool firms also received a boost with Alfred Herbert Ltd. increasing their pre-war output of machine tools by a factor of nine and its workforce of 2,000 in 1914 to 3,000 by 1918.[330] As the armaments and munitions cluster expanded, the city received considerable investment from the Ministry of Munitions for new housing, road-building and the upgrading of its power infrastructure and this was at a level far-beyond what the Coventry Corporation could have provided alone, even to meet the pre-war levels of demand.

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[327] Nowell (1927) *Coventry And The Great War*. This figure may have included spare parts and disassembled engines also.
[328] Anon (undated) *B.T.H. Our Part In the World War* p52 and *The Autocar* 1918, M-L Advert
[329] *Coventry and its Industries* 1918 p70.
[330] H.M.S.O. (1920) *History of the Ministry of Munitions;* Saul (1968) p42; Astrop (2003) p10 and Lloyd-Jones & Lewis (2006) p60.

The city was also left with two aerodromes which could potentially be beneficial to any local firm remaining in the aeronautical industry beyond 1918[331]. Upon reflection this successful munitions cluster also demonstrated to central government the flexibility and adaptability of Coventry engineering firms and its labour force when urgently tasked to manufacture a variety of new armaments and munitions in quantity day and night. This also allowed some firms to appreciate at least some of the benefits of mass-production, through large batch production of munitions to stringent government quality standards for the first time.

Negative Effects

A negative effect as a result of this successful armaments and munitions cluster was a loss of export trade, particularly for the city's Motor manufacturers who had became embroiled in munitions production as early as 1914/15. Consequently particularly American motor vehicle manufactures penetrated their foreign and domestic markets due to themselves not entering the war until 1917. A second problem arose from the unchecked expansion of the city's population which suffered overcrowding and hardship due to inadequate and expensive housing and from a shortage of food. This was compounded with a sense of 'war wiriness' due to working long hours with little time or facilities for recreation[332]. Resultantly workers within the city by the end of the war gained a reputation for striking and militancy with one official investigator noting in 1917 'the air is very highly charged here and very little will cause a great blaze'.[333] By August 1918 a Coventry journalist writing in his diary noted how the city 'stinks in the nostrils of people everywhere' because of its much publicised strike of the previous month.[334]

[331] Siddeley-Deasy, when merging with Armstrong Whitworth to become Armstrong Siddeley in 1919 eventually based their activities at the former Whitley Abbey Aerodrome in 1923 as the Sir W. G. Armstrong Whitworth Aircraft Company.
[332] Carr (1978) pp64-74.
[333] NA MUN2/28 29th September 1917.
[334] Wilkins (c.1919) *Journal of the European War* p309.

Finally many smaller undercapitalised firms were forced to close as a result of this wartime cluster, for example, as early as 8th October 1914 Hobart Bird (cycles), Crouch Motors (motor vehicles), Bramwell Bros. (sidecars) and J & J Guest (engineers) were described as 'having either the receiver in or in the actual process of being wound up'.[335] This persisted into the mid-war cluster as small car firms such as E. J. West & Company ceased trading in 1915 due to not being able to capture any vehicle contracts for the War Office or any other munition contracts.[336] Many of these implications have already been considered by such authors as Richardson (1972) and Toms & Donnelly (1985; 1986 & 2000), however, this study also revealed the existence of other less tangible effects resulting from this successful wartime cluster.

First it was shown that some engineering firms within this cluster were also tasked to exercise their ingenuity to solve engineering problems. It was these firms who were able to show an adaptability and resourcefulness towards designing and/or manufacturing novel wartime products, such as the aeroplane, tank or magneto. At the same time, these same firms were being exposed to a never-ending flux of change arising from the needs of the war. It was therefore their willingness to take on and solve new engineering challenges, despite the risks or hardships involved, which Coventry firms gained a creditable national reputation for. This fact resulted in Lord Weir (the wartime President of the Air Council) feeling compelled to visit the city in 1920 where he was given the opportunity to thank the city's manufacturers personally stating 'Coventry may well be proud of her industrial achievements'.[337]

A second and equally important lesson was the value of inter-firm and firm-governmental co-operation which for the first time in British history was demonstrated on a large scale. Despite the city's labour force gaining a negative reputation towards the end of the war, the study showed how in the mid-war cluster many of the city's manufacturers were able to work closely alongside the Ministry of Munitions through the apparatus of the Armaments Committee to achieve wartime aims.

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[335] Ibid, p41.
[336] Spicer, (2005) *West Cars of Coventry 1904-1915*
[337] C. C. C. Minutes, *Annual Banquet 1920* p15.

With the late-war cluster the study also showed how firms and individuals were able to work closely together in order design and manufacture new innovative rotary aero-engines. It would appear that a little over two weeks after the armistice, the 100 members present at a meeting of the Rugby Engineering Society (which many Coventry engineers were also members), when already reflecting upon the war and suggested 'the War had taught them two things, namely, the value of "engineering science" and co-operation'.[338] Ultimately it is these two, perhaps less visible, outcomes of Coventry's successful First World War armaments and munitions cluster, which should be considered as equally important legacies.

7.3 Evaluation of conceptual framework and methodological techniques

The extent to which the study has met the stated objectives is a key consideration in evaluating the success of the research. Three research strands were drawn together to provide a meaningful conceptual framework: i) Markusen's (1996) industrial district models, ii) The more recent work on clusters involving a greater scrutiny of both tangible and intangible linkages and iii) to incorporate this with theory of the innovative milieu. It is argued that the research provided an original insight into Coventry's First World War armaments and munitions industry by conceptualizing it as an evolving cluster of firms linked to support institutions and infrastructure over time (1914-18) and space (both within and slightly outside Coventry's municipal boundary). As explained in Chapter 1, it was timely to examine broadly this industry as this had not been attempted before and according to Chapter 2 previous industrial agglomeration studies had ignored wartime case studies.

The insight this study provided was Markusen's (1996) industrial district models can be applied to a past British wartime industries. The study was also able to suggest ways in which this industry was successfully transformed from one cluster type to another over a period spanning only four-and-half years. During the mid-war cluster a novel way in which an economy can be conceptualized as a state-anchored/centred cluster (centred largely upon a committee) was demonstrated.

[338] *Rugby Engineering Society Minutes*, 28th November 1918 p26.

Furthermore this study was able to represent this cluster type spatially which was something Markusen (1996) didn't attempt. The importance of business or social networks to a historical clusters operation was also shown in this mid-war cluster. This and the other cluster forms which were revealed suggest that these industrial district/cluster models are in need of more careful refinement, especially in light of historical industries and wartime contexts. Finally by relating the late war cluster to the innovative milieu concept it was revealed how complex and multifaceted an early twentieth century local industrial cluster can become.

A complementary two-phase extensive and intensive methodology was selected as the most appropriate strategy to reveal and explain the complex and evolutionary nature of this wartime industrial cluster. In revealing the extent of this cluster, the extensive phase uncovered all 76 government "controlled establishments"[339]. Additionally another 61 still privately operated munition firms within Coventry were also identified. The study also highlighted 13 support institutions and infrastructure involved in forming the linkages between these firms. This was summarized through a series of tables and maps in Chapter 5. Although this may only be a representation of the entire wartime cluster, when considered against a number of locational, historical and situational constraints outlined in Chapter 3 this was no mean achievement.

It is accepted that changes to certain aspects of the methodology may have provided additional insight and made a greater contribution to the research aims. Firstly, due to time and financial constraints further business records located in Manchester, Birkenhead and London were not consulted. These sometimes included restricted business records where permission to access them was granted, for example, Coventry Ordnance, Coventry Chain, and Coventry Repetition Companies respectably[340].

[339] This is confirmed as official documentation for the many thousands of controlled establishments in Britain was located and consulted in the National Archives. See NA MUN4/750, MUN4/3618, MUN5/101/360/16 & MUN5/254.

[340] For example Renold Chain's permission was gained to examine the records of Coventry Chain and Coventry Repetition. In the end after selecting what was relevant to examine, Manchester Archives were not willing to photocopy or could not locate many of the required documents and would only allow access through visitation.

In London, further time could have been spent at the Imperial War Museum listening to recorded interviews of WW1 Coventry munition workers[341]. At the National Archives further consultation of the Ministry of Munitions, Admiralty, Air Board and Ministry of Aviation records could have possibly revealed more on certain Coventry firms activities. Despite this, all documents that could be identified to contain wartime information on Coventry was consulted.

Secondly, further information as to the growth and performance of firms may have been forthcoming by examining any surviving bank records. Some of these for Coventry firms are contained within the Midland and Lloyds Bank archives in London[342]. These records may have also provided additional information as to how firms financed their wartime growth, possibly through bank loans, overdraft facilities or issuing more shares. Thirdly, as this study wished to examine a wartime cluster composed of engineering firms from many different sectors, this made a complete examination of all the trade press literature difficult. Where possible key publications were consulted locally[343] but a visit to the Newspaper Reading Room, British Library, in Colindale, London would have allowed a complete wartime examination of the more esoteric trade journals including amongst others: *Arms and Explosives, American Machinist, The Industrial Engineer, Aeroplane, Aircraft, The Drop Forger, Electrical Review, Electrical Engineering, English Electrical Journal, The Metal Bulletin, Monthly review of Machine Shop Practice, Motor cycle and cycle trader, Vehicle monthly* and *Woman Engineer*.

Despite this the evidence base used for this study was robust and extensive, with both the extensive and intensive methodology phases contributing effectively to meeting the research aims.

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[341] In all this collection holds ten interviews with men and women workers in Coventry's WW1 munitions industry, only the 5 with transcripts were consulted for this study.
[342] See Thoms (1992) *Bank Records and the Early History of the Coventry Motor Car Industry*. pp38-42. In particular Midland Bank Archive, London – Coventry district, daily journals MBA 358 and Lloyds Bank Archive, London – Coventry district, daily journals LBA B379a
[343] Such as *Autocar, The Motor, The Engineer, Engineering, Alfred Herbert News, Machine Tool Review and Flight* for the years covering the 1914-1918 war. See bibliography for the full list of trade journals consulted.

7.4 Directions for Future Research

There are a number of areas which have been highlighted as pertinent issues within cluster theory and Coventry's industrial development by this study which would benefit from further research. In terms of Coventry's industrial development in the twentieth century, further research is necessary to reveal the extent and evolution of the metal-working, electrical engineering and aeronautical sectors. All three of these sectors are left largely unexplored within the broad debate of Coventry's remarkable 'boom town' reputation that lasted until the 1970s. This study revealed that all three of these sectors expanded as a result of First World War munitions production. However, it isn't clear if this diversified and reinforced this prosperity or perhaps helped to narrow Coventry's light engineering base and leave it more susceptible to the severe de-industrialisation which swept across the West Midlands and other parts of Britain during the 1970s and 1980s.

A second area for further research is to address whether the city's manufacturers absorbed and applied any wartime lessons into the interwar years. For example, how did manufacturing to high quality standards and in larger quantities than ever before, affect firms engineering, shop-floor and management practices. This is an important question as according to Toms & Donnelly (1985 & 2000) most of the volume producers in the motor industry chose not to assemble their vehicles in Coventry in the interwar years. Apart from Singer (later to become part of Rootes), Standard and Hotchkiss (which became Morris Engines) no other motor firm in the city embraced volume production. The same could be said for the city's cycle and motorcycle firms where firms such as Rover, Rudge Whitworth, Humber and Coventry Premier never regained their pre-1914 leading positions. Furthermore Triumph went from a position as the leading motorcycle manufacturer in 1918 to bankruptcy by the mid 1930s. Related to this point was the negative reputation the city gained towards the end of the war as an area prone to labour unrest. Further research is therefore needed to answer whether it was this, or other reasons emanating from Coventry's successful munitions cluster, as to why Coventry's leading position as the centre for the British cycle and motor industries was successfully challenged in the interwar years.

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