Conceptualizing the Field of Operations Management

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This paper will report a bibliometric analysis (essentially co-citation network analysis) of *POMS*. As well as introducing the fundamental ideas of bibliometrics, some results relating to the nature of OM will be presented.

Network analysis tools will be shown which identify and explore central concepts covered by OM and their inter-relationships. Specific results to be presented will cover different levels of analysis and so show different dimensions which can be extracted form citation data:

- Co-word terms from article keywords used to identify themes
- Journal title co-citation network: link OM to other disciplines
- Individual publications co-citation networks used to show concentrations of underlying themes and how they relate
- Author co-citations used to identify the most important individuals

An early result is that citation patterns of publication titles show that OM has a bridging role in integrating ideas from several distinct disciplines. Particularly, general management, OR and strategy journals feature prominently alongside the OM specific journals. This suggests that strategy and management are central to OM which essentially relates to the firm rather than wider contexts and markets.

Keywords: Operations management, bibliometric techniques, co-citation, citation analysis, social network analysis.

Introduction

On the opening page of the first issue of the *Journal of Operations Management (JOM)*, Elwood Buffa declared that Operations Management (OM) had emerged from a period of OR/Management Science research and expressed the belief that "future research is felt to be embodied in projects that are of broader managerial scope, reflecting relationships between subsystems and interfunctional effects. Evaluative criteria should reflect the multiple criteria realities of the managerial world" (Buffa, 1980). Despite these directions, we struggled until late to establish ourselves as a distinct academic discipline (Meredith *et al*, 1989; Swamidass, 1991; Chase and Prentis, 1987). The lack of success has been attributed to many reasons, including the preference of OM researchers to publish their best work in the established journals of other fields, such as *Management Science, Operations Research, Decision Sciences,* and the *Academy of Management Journal* (Barman *et al*, 1991). The importance of publishing in established and respected journals only partially explained why career conscious academics hesitated to submit their ideas to OM-specific journals. Amundson (1998), in examining the development of other disciplines, suggested that OM was suffering "in the creation of formal, research oriented theoretical perspectives" because of its size, and inherently interdisciplinary nature. Sower *et al* (1997) agreed and found the major obstacle to be the subject's unusually high degree of interaction with other disciplines. This overlap blurred the boundaries of OM and as a result its distinct theoretical models and analytical tools were unjustly attributed to competing fields. Pilkington and Liston-Heyes (1999), argued that the early blurring was exacerbated by substantial differences in interests and approaches by OM scholars in North America relative to their European counterparts. They argued that cross-fertilisation of ideas between authors on both sides of the Atlantic was needed to make distinctive themes and approaches for OM.

Despite these difficulties, OM appears to be gaining momentum as a respected academic discipline (Ketokivi and Schroeder, 2004; Pagell and Krause, 2004), largely through the availability of strong and respected publication outlets such as *POM, JOM* and *IJOPM*. Now is a good time to take stock of what it is that makes OM distinct and reflect on how far we have managed to achieve Buffa's goals of multiple criteria for the manager's world. This paper empirically investigates this by identifying the recent themes and approaches in OM research as recorded in the citations of *POM*. Specifically the paper examines the central themes of OM using network analysis techniques, to determine the underlying structure of the OM literature. In addition, associated tools are used to plot small and recent clusters of themes which may represent new foci for OM research. The paper starts with a brief review of similar bibliometric studies to introduce the approach, followed by a description of the data, before discussing the results.

Studies of the Academic Literature

There are a number of techniques that can be used to examine a body of literature. Most frequent is the simple literature review where a highly subjective approach is used to structure earlier work, as in the review of manufacturing strategy by Anderson, Cleveland and Schroeder (1989). More objective, quantitative techniques are also available and use an analysis of citations, co-citations, or a combination of the two. Citation analysis is based on the premise that authors cite papers they consider to be important to the development of their research. As a

result, heavily cited articles are likely to have exerted a greater influence on the subject than those less frequently referenced (Sharplin and Mabry, 1985; Culnan, 1986). There are well defined concerns surrounding citation analysis, including the problem that a study may be heavily referred to due to its poor quality. However, with adequate screening and a sufficiently large sample, citation analysis provides a useful insight into which papers and authors are considered influential. As such citation analysis represent "the field's view of itself" (White and Griffith, 1980). Similarly, co-citation analysis involves analysing the frequency with which two citations appear together in the literature. The approach is instrumental in identifying groupings of authors, topics, or methods and can help us understand the way in which these clusters relate to each other (Small, 1973). Normally the common interests in the body of citations are extracted using factor analysis or MDS of the correlations in a co-citation frequency matrix to identify the implicit dimensions.

The standard approach to source article selection is to use a panel of experts to identify a sample of prominent authors in a given field and identify and retrieve any papers which cite any of their articles. This population is then the subject of the analysis which occurs at this cited author level. As such, authors are used to act as a proxy for the ideas and contributions of their papers and books. This represents a trade-off in detail of analysis which results from the original identification of the source articles – retrieving articles which cite particular authors is far simpler than identifying articles which cite all articles by the authors. In this study, the normal author co-citation analysis (ACA) method, with its proxy of author for idea, has been improved by using the *POM* as the source population. As a result, we can perform the analysis at the individual publication level giving a more detailed representation of topics discussed, particularly given that prominent authors in an emerging field are likely to have made contributions in a number of areas.

A number of bibliometric analyses have been performed on the literatures of fields adjacent to OM. For example, Culnan (1986) used co-citation analysis to investigate the founding pillars of management information systems and found the subject to have more affinity with information science than organisation studies. Similarly, Karki (1996) examined the sociology of science literature and found that information scientists and sociologists exchange ideas only when they are discussing 'scholarly communication' as a subject. Cottrill *et al* (1989) investigated the traditions of innovation research and the links between its sub-fields of 'diffusion theory' and 'technology transfer'. Somewhat surprisingly, they found the use of distinct approaches within each sub-field that rarely interacted with each other.

To the best of our knowledge there is only one bibliometric study of the field of OM (Pilkington and Liston-Heyes, 1999) which explored *IJOPM* citations to plot its sub-fields, and they identified that researchers from different parts of the world perceive OM to cover significantly different sub-fields. Other related studies include Sower *et al* (1997) who surveyed OM teachers to compile a list of texts and articles viewed as the classics of OM. Whilst this gives us a historical insight into how OM is communicated to students, it does not provide us with a contemporary view of the subject or its theoretical structuring. Similarly, Agrawal (2002) compared OM journals based on the ranking of the schools of the authors. This may be useful for authors in considering where to focus for maximum impact, but it doesn't say much about the development of the discipline itself. These questions can be answered by using the citation/co-

citation approach chosen here.

Data Collection

The data used in this study included the recent contents of *POM* between 1999 (Volume 8, Number 1) and 2005 (Volume 14, number 1). This study is part of a wider study to examine innovation and OM and so reports preliminary results of the analysis of *POM.* The other leading titles in OM: *JOM* and *IJOPM* have also been studied, and further work is needed to develop the tools and data to provide a combined analysis of all the titles. However, selection of *POM* is supported by its prominence in the field of OM, wide geographical coverage, and ease of access because of its inclusion in the Social Science Citation Index (SSCI).

The initial extraction of the data from the SSCI resulted in 191 articles featuring 333 different authors – the discrepancy arises from articles with multiple authors and authors with multiple articles. Table 1 shows those authors who wrote the most source articles.

Table 1. Authors Contributing Articles to the Sample

Source Article Author	Number of Articles
Corbett CJ	5
Souza GC	4
Sethi SP	4
Yan HM	4
Kleindorfer PR	4
Johnson ME	4
Parker GG	3
Hayes RH	3
Guide VDR	3
Stewart DM	3
Jack EP	3
Boyer KK	3
Narasimhan R	3
Seshadri S	3
Roth AV	3
Anderson EG	3

***** Note that editorials and other regular contributions are included in the sample and this may account for some of the high scores.

A certain amount of manual manipulation was required to standardise the citations and correct for inconsistencies in the SSCI. One area needing intervention was journal titling, where, for example, at least three different abbreviations are used for the *International Journal of Operations and Production Management: IJOPM, IJOpProdMan* and *IntJOPM*. Similarly, author's names included one or two initials and it was decided to standardise on the first initial,

with a simple check of frequency tables suggesting this caused no issues of conflict in attributing citations to non-unique authors. There was also a need for the years of texts to be checked manually, particularly when there are multiple editions. For example, the *Multivariate Data Analysis* text by Hair *et al* has five editions (1984, 1987, 1992, 1995 and 1998), but was most often cited in the data as 1992, its third edition.

The source articles produced 6,377 citations, but after multiple citations in the same source article and entries with missing data (often publication year for in press articles) were removed, 6,331citations were taken forward into the analysis, listing 2,045 different titles (journal, book or series) and 3,230 first authors.

Results

Preliminary analyses of the data produced interesting background statistics, for example the frequency of journal citations, listed in Table 2. The table shows the wide range of titles and interests of articles in the *POM* covering not just operations but also management science, general management, and strategy. It was surprising to see the high ranking of marketing titles in the citations, but further investigation shows that this is a result of sourcing methodological developments rather than an interest in the marketing discipline or how it relates to operations. The significance of the *POM* in the discipline is confirmed by its high ranking in Table 2. The table also provides evidence of how operations is distinguished from its more esoteric cousins OR and management science as there is a high presence of management journals such as the *HBR*, and those from the Academy of Management and Sloan School. This shows the immediacy and practical nature of operations, something which can be said to be missing from the more mathematically focussed modelling approaches of others.

Table 2 is comparable to that compiled in the early 1990s by Barman *et al*, on the most relevant journals to OM (1991: 207) and Vokurka's journal rankings (1996). However, comparison shows a noticeable shift with the more recent citation data being dominated by general management and strategy whilst the older studies show more emphasis on OR and production. The observed decline in placing of titles such as *IJProd Res, IIE Transactions, Omega, Eur J OR, OR, JOR Soc* suggests we are starting to follow Buffa's advice on developing a distinct path of our own for OM.

Table 2. The Most Frequently Cited Publication Titles

Cited Title	Frequency
MANAGE_SCI	486
PROD_OPER_MANAG	329
J_OPER_MANAG	204
HARVARD_BUS_REV	203
OPER_RES	175
EUR_J_OPER_RES	143
DECISION_SCI	116
IIE_TRANS	86
J_MARKETING	82
SLOAN_MANAGE_REV	81
INT_J_PROD_RES	76
ACAD_MANAGE_REV	67
STRATEGIC_MANAGE_J	63
INTERFACES	62
INT_J_OPER_PROD_MAN	62
J_MARKETING_RES	59
CALIF_MANAGE_REV	54
J_OPER_RES_SOC	52
ACAD_MANAGE_J	50
NAV_RES_LOG	46
PRODUCTION_INVENTORY	44
MARKET_SCI	39
J_RETAILING	38
INT_J_PROD_ECON	31
QUANTITATIVE_MODELS	30
MANUFACTURING_SERVIC	29
OMEGA-INT_J_MANAGE_S	25
SUPPLY_CHAIN_MANAGEM	25
ADM_SCI_Q	25

Table 3 presents the frequencies with which a particular document has been cited. This is a means of identifying the true classics in OM literature as these are the publications which are most widely referenced in current research. Although it does not eliminate the bias against younger authors, an article-based ranking places more emphasis on the quality (as opposed to the quantity) of the documents produced by a given author than a ranking of the frequencies with which a particular author has been cited. As such, Table 3 suggests the focus of the main authors in the field and indicates the popularity of certain OM topics.

Table 3. The Most Frequently Cited Publications

Cited Publication	Frequency
LEE_H>MANAGE_SCI>1997	15
SKINNER_W>PROD_OPER_MANAG>1996	15
HAYES_R>RESTORING_OUR_COMPET>1984	12
NUNNALLY_J>PSYCHOMETRIC_THEORY>1978	10
STERMAN_J>MANAGE_SCI>1989	10
MILLER_J>MANAGE_SCI>1994	9
CHASE_R>OPER_RES>1981	9
HAIR_J>MULTIVARIATE_DATA_AN>1995	9
ROTH_A>MANAGE_SCI>1995	9
GERWIN_D>MANAGE_SCI>1993	9
KLASSEN_R>ACAD_MANAGE_J>1999	8
CORBETT_C>PROD_OPER_MANAG>2001	8
WOMACK_J>MACHINE_CHANGED_WORL>1990	8
HAYES_R>PROD_OPER_MANAG>1996	7
FLYNN_B>DECISION_SCI>1995	7
HILL_T>MANUFACTURING_STRATE>1994	7
SKINNER_W>HARVARD_BUS_REV>1969	7
FERDOWS_K>J_OPER_MANAG>1990	7
WALLEY_N>HARVARD_BUS_REV>1994	7
GARVIN_D>HARVARD_BUS_REV>1987	7
SKINNER_W>HARVARD_BUS_REV>1974	7

The top item addresses a specific aspect of OM – Lee's article on the bullwhip effect in supply chains. However, this article is probably the only one in the list which does deal with SCM, there fore questioning the importance of the discipline to OM. This question can be analysed when we move into more depth of this study.

There is little surprise that the classic OM defining works of Hayes and Skinner feature in the list when they represent the foundations of the discipline and manufacturing strategy in particular. This topic is well represented elsewhere in the list, suggesting that it is the main focus of the OM literature, see for example Miller (1994), Gerwin (1993). There is also a number of articles which deal variously with quality and performance which shows our interests in measuring the impact of quality on firm performance: Roth (1995), Klassen (1999), Flynn (1995) and Garvin (1987).

Examining the list shows traditions are based solidly on manufacturing, with only two of the top 21 publications not concerned with manufacturing (and these refer to research methodologies). In the light of the discussion above on the rise of general management, it is disappointing to find few competitive strategy articles near the top of the table and this suggests we have still not integrated manufacturing with corporate strategy – it appears Skinner's early observations which led to the formation of OM and the comments of Hayes and Pisano (1996) remain as acute as ever.

Table 4 similarly shows the frequencies of authors of the cited articles. It has to be noted that this is based only on the first authors of publications and so does not give a complete picture of the influence of individuals who often feature as part of a team. As such the implications from the table should not be given undo attention, but it does offer some insights into the influence of individual writers in the discipline. Whilst Lee and the work on supply chains feature at the top of the list, and Hayes and Skinner (manufacturing strategy) further down, offer no surprises, the high scores associated with Flynn (and the World Class Manufacturing Survey team) and Roth (service quality) seem worthy of mention. It is interesting to note that there are few authors from outside North America in the list.

Table 4. The Most Frequently Cited First Listed Authors

Cited First Author	Frequency
LEE_H	60
CHASE_R	52
SKINNER_W	40
HAYES_R	38
ROTH_A	33
FLYNN_B	29
FISHER_M	27
KLASSEN_R	27
CORBETT_C	27
CACHON_G	26
COHEN_M	24
SCHMENNER_R	24
GUIDE_V	23
RUST_R	23
PORTER_M	23
FINE_C	22
ANDERSON_J	22
BITRAN_G	21
BOYER_K	21
CHEN_F	20

Whilst the tables above give us some insight into the field and represent a fairly standard citation analysis, the method does not give a clear account of the concentration of interests within the field. We address such issues by performing various analyses on the co-occurrence matrices which can be produced from the data. Co-occurrences are counts of the frequency with which two existing elements appear *together* in a document and their analysis enables us to say something about the way ideas support and interact with each other and also to plot the structure of intellectual disciplines (Small, 1973; White and Griffith, 1981). The co-occurrence analyses were performed using several different tools. Data extraction, manipulation and co-occurrences were tabulated using the bibliometric analysis package *Bibexcel* from Olle Persson (2003), and the networks analysed and drawn using UCINET and NetDraw packages from Borgatti, *et al,*

(2002).

Keyword Co-Occurrence

A simple but useful approach is to examine the way that authors select key words to identify the subject of their articles. By aggregating the keyword information, frequently co-cited topics can be identified and the relationships between different areas represented diagrammatically. Figure 1 is an MDS representation of the most used keywords for the *POM* articles and shows those words which appear more than 3 times in the sample. The diagram identifies the focus as determined by the authors of the original articles, and splits neatly into three groups for *POM* which can be named by inspection, and it is hoped to use this data as a source of discussion at the conference: what links these ideas?

However, these terms have relatively low frequencies and are selected by the authors of the original articles without using a common process and so are maybe not as robust as the measures of co-occurrence we investigate below.

Figure 1. Keyword Co-occurrence MDS

Co-citation Analysis

Co-citation analysis can be applied to different levels of aggregation: on the level of single publications, it can be used to study relationships among specific conceptual ideas or empirical findings (Small, 1973). At a highly aggregated level, an analysis of co-cited journal titles can investigate patterns in the generation of scientific knowledge (Rost, Teichert, 2004). At

an intermediary level of aggregation, author co-citation analysis (ACA) provides insights about underlying schools of thought in scientific discourse (White, Griffith, 1981). Joint citation occurrences of author pairs are used as raw data, no matter what piece of their works is being cited. Thus, ACA shows how actors are positioned relatively to each other in a research field.

All these aggregated levels of information rely on the co-citation matrix – a cross referenced grid of co-appearance frequencies for the citations in the sampled documents.

On analysing the co-citation matrix, it was found that there was a centralisation towards a common highly interlinked set of literature which dominated attempts to identify the different sub-fields using statistical analysis – the standard ACA approach is a factor analysis of the correlations of the co-citation matrix to extract the latent dimensions and so describe the structure of the relationships (Pilkington and Liston-Heyes 1999). Whilst the factor analysis produced interesting results, there was considerable overlap in the areas which made interpretation difficult as many citations loaded onto several factors. The factors which were extracted mostly appeared to have a persistent dimension and were not associated with particularly high eigen-values, indicating that the dimensions were not particularly distinct. Similar issues were found when normal cluster analysis techniques were used, as multicollinearity in the frequency measure became an issue. In view of these difficulties, alternative approaches based on social network analysis (SNA) were adopted. SNA represents a number of tools which have been developed to study the players, their centrality, roles and topology of social networks (Scott, 1991).

Journal Co-citation: Discipline Span

One of the primary aims of the authors in performing this research was to establish the coverage and academic antecedents of *POM* itself. In establishing the remit of the journal we can offer advice on publication opportunities and also discuss the way that OM as a subject has developed and also whether it is emerging as a distinct discipline in its own right. In order to examine these features, we first studied the co-citations at the publication title level of detail. A co-citation matrix was constructed but which only recorded journal titles, and included the top titles which each gained 7 or more citations in the data set. From this data, the most commonly co-cited journals in OM (those which had co-citation scores greater than 28) are shown diagrammatically as a network with locations determined using euclidian distances. The resulting graph (Figure 2) has thicker lines representing the very strongest ties, and the size of the circle representing the number of times each journal was cited in the data set.

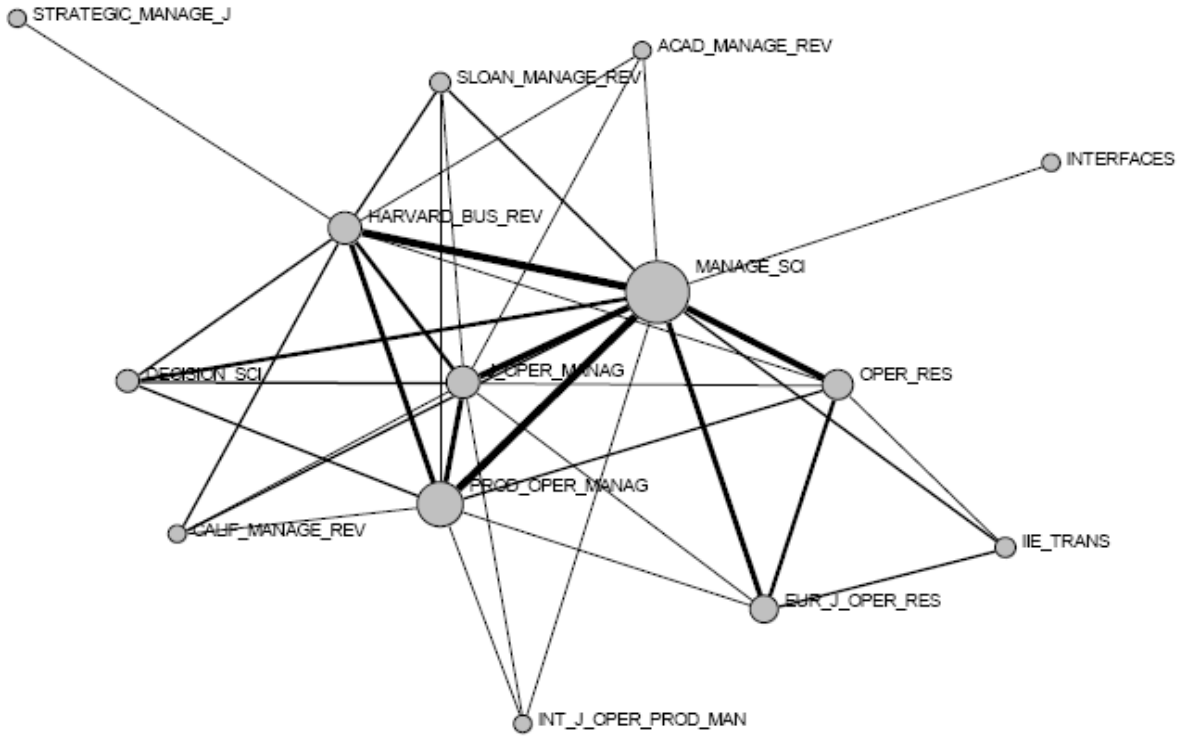

Figure 2. The Most Central Journals in OM:
MDS of Journal Title Co-citations greater than 28.

Figure 2 shows that OM, as represented by the contents of *POM*, has an unsurprising focus on OM titles themselves (*POM, JOM, IJOPM*) but also has a strong role in linking together OR and general management and strategy specific areas. A possible cautionary note from this result (and Table 2 earlier) is that the central journal in OM can be argued to be *Management Science* and not one of the OM specific titles. This is perhaps an issue of perceived quality and age of the OM discipline. For career development it is important to publish in places respected by peers from different disciplines and as such Management Science ranks higher than any of the OM specific journals.

Individual Publication Co-citations: Relations amongst Topics

Investigation of Figure 3 clearly shows that the core literature has several themes: operations strategy, information modelling, environmental resources, and satisfaction measures. The observation that operations strategy is at the very core of interests of the *POM* and OM literatures is not unexpected. However, it is interesting to note that this includes a range of different approaches and sub-topics which are separated on the diagram with a focus near the top on capability based approaches with a majority of fairly recent articles, such as the Ferdows and DeMeyer (1990) and Hayes and Pisano (1996). The middle part of the OM strategy chain in the diagram shows a Skinner's early assertions for the need for manufacturing strategy, whilst the literature in the lower section of the diagram examine sources and taxonomies of manufacturing advantage, and necessarily have a more prescriptive bias.

Slightly to the left of the diagram we have another major focus, as judged by the size of the circles which represent the number of times each article was cited. This group examines modelling of management issues and is dominated by J.W. Forrester, but also includes aspects of the information distortion as seen in the bullwhip from Lee (1997). It could be that this group represent the philosophical grounding of OM as being based on industrial dynamics and so this body of literature is cited in the introduction to many papers in *POM,* however it may represent the core ideas of a common group of literature which deals with modelling as a whole.

On the right of the diagram is a small group concerned with the role of environmental resources as manufacturing constraints and opportunities: Klassen and Whybark (1999) and Hart (1995). On the right we also have a small group from the marketing perspective which is concerned with specific measures of performance: Bolton (1991) and Cronin (1992), showing a central interest in linking performance to customer satisfaction.

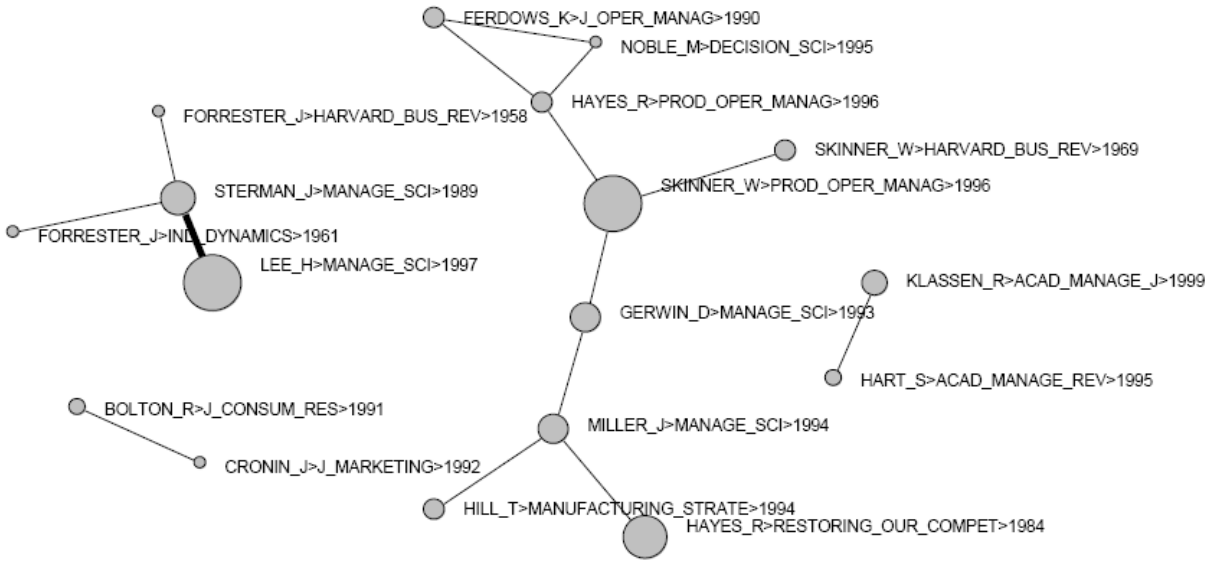

Figure 3. The graph of the Core literature in OM:
Co-citations with frequencies greater than 4.

Author Co-citation Analysis: Subjects

In order to investigate the subjects of interest to *POM* and whether the ideas from different disciplines are being integrated to synthesise new subjects or approaches we performed an analysis at the slightly lower level of aggregation of author. Such author co-citation analysis (ACA) as pioneered by White and Griffith (1981) is a fairly well established technique in which citations are attributed to the first cited author and as such the authors stand as a proxy for the ideas of their publications. A major concern with the technique is that the SSCI only lists the first author of the articles cited, and as such the results can often leave out the contributions made as a second author. Figure 4 shows an MDS representation of the co-citation matrix for the most cited authors, and with co-citation frequencies greater than 7. The size of the circle

represents the number of citations each author receives, and the thickness of the lines relates the strength of the co-citation link.

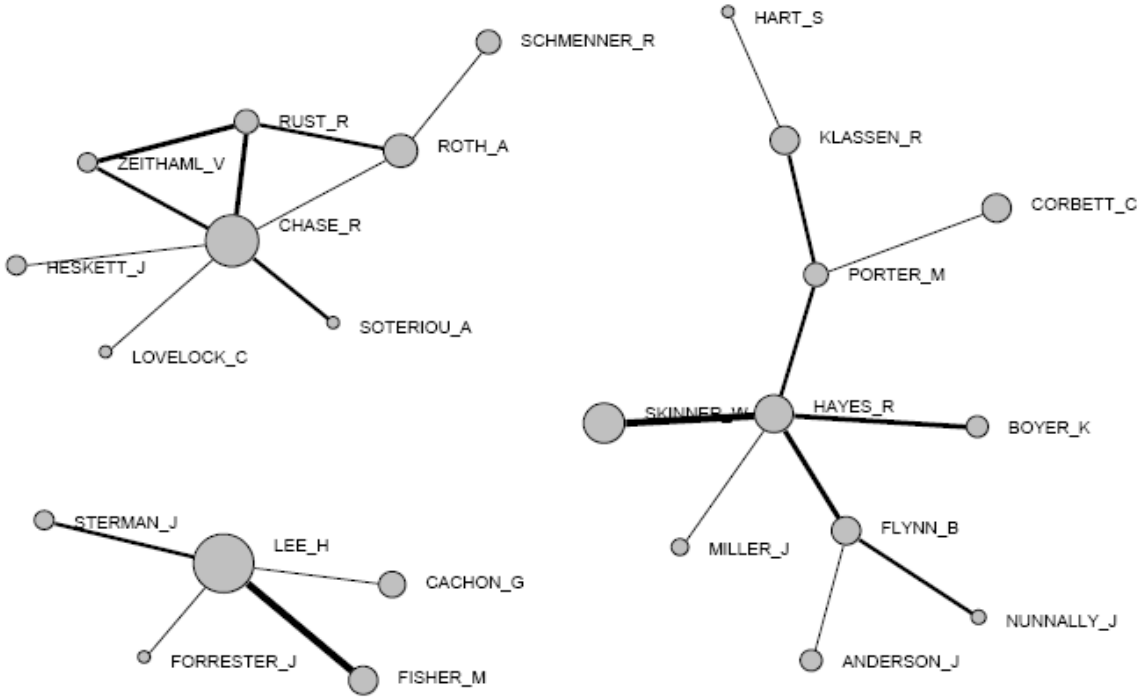

Figure 4. Author Co-citation Network:
Showing co-citations greater than 7.

Figure 4 identifies the most important authors in OM and also shows how their ideas group together and then how these groups relate to each other. Preliminary inspection suggest that OM has three main schools of thought and it is hoped that presentation at the POMS conference will allow solid names to be given to these during discussions.

Conclusion

This paper has shown that citation/co-citation studies, when coupled with network analysis techniques, have the power to investigate the intellectual structure of an academic discipline. These techniques have been employed to identify not only the main interests and sub-fields, but also the evolution of research streams. The literature patterns in *POM* show the main areas of interest of OM researchers to be operations strategy and supply chain modelling which dominate every aspect of our work. These are different from the standard definitions offered in the introductory sections of OM text books, which perhaps could be revised in the light of these findings.

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