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From supply chain to welding network: A framework of the prospects of networks in welding

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1. Introduction

Study of supply chains and business networks has become an important aspect of efforts to enhance efficiency in industrial manufacturing and modern business. It is generally accepted that business is becoming increasingly global [1-3] and competition becoming increasingly intense. This transformed business environment has changed manufacturing processes, especially connections between different functions in commercial activity, and has promoted the adoption of new technologies.

A business network can be defined as a set of nodes and the set of ties depicting the relationship between the nodes [4]. It has been suggested that networks with well-coordinated and managed connections between the different parts of the network and their actions can gain considerable benefits as regards organizational competitiveness [5]. Network studies can comprise different views depending on the focus of research and the perspective used to interpret the results; for example, network modeling can provide valuable information about network behavior [2, 6, 7]. Such modeling is an approach that gives a comprehensive overview of a network.

However, the variety of approaches used in the field have led to a lack of clarity regarding the conceptual division between supply chains and networks. Furthermore, despite the considerable amount of research, there is a lack of work dealing with specific fields of manufacturing, their characteristic functions and requirements. Additionally, it is not clear whether a supply chain or network approach is predominant and how the two approaches perform in specific manufacturing contexts. It is of interest to observe how different manufacturing processes in different industrial fields emphasize different linkages between different functions.

The purpose of this paper is to elucidate the network concept within the context of the welding industry. The paper reviews background information about networks and compares this theoretical information with practices in welding manufacturing. The paper studies the common attributes of welding networks and welding manufacturing chains dominated by a focal firm and presents an example of the internal and external linkages of a welding network.

The study is based on analysis of welding networks involving small- and medium-sized companies. In the empirical part of the work, the structure and different levels of welding networks were defined using experimental information about welding networks. The data was collected in 2010 to 2013 and is based on three welding networks consisting of three to four small- and medium-sized companies with welding workshop activity. The network structure in its entirety consisted of a larger number of firms. The linkages were defined experimentally and using data collected in numerous interviews, and from observations and production data. The observed linkages were followed upstream (suppliers) and downstream (customers), with focal firm dominance, and both internal linkages and external linkages of the welding network were explored. The paper also discusses increases in the profitability of welding functions that may be possible as a result of increased cooperation in the network.

2. From manufacturing supply chains to welding networks

Supply chains of many fields of industry have been studied by many authors, and the different parts of the manufacturing chain have been designated throughout its whole length, from raw material to final product and customer [8]. A typical supply chain contains the functions of supply, manufacturing, distribution and retailers or consumers [9-11]. Supply chains consist of many firms, which are defined by their individual relationships to each other [6]. Intercommunication in a supply chain is however commonly dyadic, e.g., between a supplier and customer (Fig. 1). The functions in the different parts of the supply chain have been surveyed from many different perspectives, from individual manufacturing processes to the economic life cycle of the manufactured product.

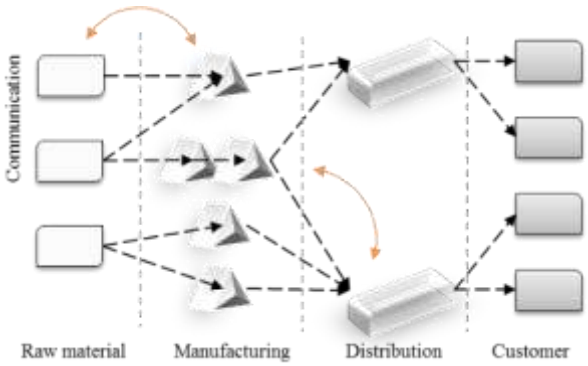

Fig. 1 Typical supply chain with dyadic intercommunication (Adapted) [10]

When making efforts to develop greater efficiency in the supply chain, the need to understand its business processes and linkages becomes more important [8]. Thus,

the focus of research interest has shifted from viewing manufacturing processes in isolation to consideration of the different functions of the relationships within the supply chain. While much research still focuses on consideration of only one tier of the supply chain relationship, investigation of multiple levels of relationships and the various dynamics in communication and cooperation at an organizational level is becoming more prominent [4, 6]. The development of more complex relationships in the supply chain is leading to a greater emphasis on the network perspective.

The dividing line between supply chains and production networks is not clear-cut. Many authors [7, 11-17] describe business processes and manufacturing as being a part of the supply chain network. The conflated concept of supply chain and business network illustrates the change in business management viewpoints, but also illustrates the conceptual complexity of describing supply chains and manufacturing [18, 19] and uncertainty in business processes. Research interest in business networks has increased over the last decades as the importance and prevalence of networks has become evident [1].

Networks are considered a complex environment for managing business processes [20] formed of many suppliers who are participants in different relationships with many actors and tiers [12]. The complexity and multiple relationships in networks mean that they are strongly dependent on cooperation [3, 4, 21]. It is important to realize that strategic and management approaches differ when stepping from an individual firm perspective to a network environment [12]. Organizations aspire networks for a variety of reasons. However, one of the specific reason, in a general sense, it make possible to achieve some end that they could not have achieved independently [5].

Networks can also be seen as consisting of many supply chain strings which have linkages [21]. Network members with linkages are known as nodes in the network [4, 12]. Fig. 2 illustrates the complexity of networks and the possibility of multiple supply chain structures involving members in a network. The dashed line emphasizes the prospect of one particular manufacturing path in a network of possible route choices, illustrated with a continuous line.

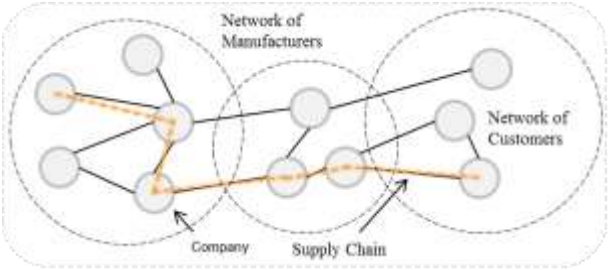

Fig. 2 Generic network structure of operations and linkages

In conventional supply chains and supply chain networks, the complex structure of relationships affecting business processes is not seen as strongly as in production networks. There is no strict division differentiating the network itself from the supply chain network but there is a fine noticeable difference in the complexity of the network structure and behavior of participants of the network. For example, a supply chain can be described as a network of companies [6] and facilities and distribution entities [11], and a supply chain network can consist of member firms and the links between them [18]. The network can have the same facilities, but the network view is an aggregated view of suppliers, the focal firm and customers [12].

Networks can be studied from many different perspectives. For example, network design and modelling, and network management and manufacturing processes are of interest in many studies of the global business environment. Depending on the perspective, particular aspects of networks can be observed, e.g., variables related to material supply, component fabrication, manufacturing, and final product distribution activities [7], or production, inventory and transportation [13], or manufacturing, storage and distribution [14]. Table 1 presents some recent research on network behavior based on the perspective and network aspects chosen for study.

Table 1
Perspectives of some recent research on networks divided by approach of network study

Approach	References
Network design and modelling	[2], [6], [7], [13], [14], [16], [20], [22], [23], [24], [25]
Network management	[15], [26], [27], [28]
Network Quality	[16], [17], [29]
Network relationships and cooperation	[3], [6], [12], [21], [27], [30], [31], [32]
Finance and economics in networks	[7], [14], [16], [17], [20], [25]
Network flexibility	[11], [33]
Uncertainty of network	[20], [15], [28]

Production networks often appear to have the same base facilities as supply chains [e.g. 14], that is, supply chains and networks include cognate entities in some instances. Nevertheless, both have their own distinguishable characteristics (Table 2). A key difference is that the combined effect of production chain management and business processes are analyzed at different levels and evaluation criteria for suppliers and customers differ. Generally, a network-based approach concentrates more on managing relationships between firms, and the business processes involved are more multi-tiered than dyadic. When comparing networks and supply chains, the focus of operational strategy is both vertical and horizontal in networks, rather than only vertical as in supply chains [1].

Table 2
Differences between supply chains and networks according to different approaches

Approach	Supply Chain	Network
Main focus area	Inter-firm	Intra-firm
Focus of linkages	Focus on the nodes	Focus on linkages between nodes
Focal firm	Focal firm dominant	Multiple focal firms
Manufacturing perspective	Suppliers – Manufacturer – Customer	Supplier network – Manufacturing network – Customer network
Coordination of manufacturing	Focal firm	Equivocal
Cooperation	Dyadic	Strongly dependent on cooperation at multi-tired levels
Cooperation direction	Vertical	Vertical and horizontal

In view of the fact that supply chains and networks appear to have their own distinguishable attributes, there is an unsystematic convention when using the supply

chain or network notion, which, to a certain extent, seems to depend on the nature of research. The research view of networks appears to differ depending on the focus of the study. Furthermore, the functions, design and management of operations also seem to differ. This discrepancy in different aspects of network research is indicative of a need for more examination, particularly as there has been a lack of practical studies in network research in the last decade [22]. At present, there is a need for empirical network research of different aspects of business functions in different sectors of the manufacturing industry [15].

Researchers have observed networks from different viewpoints or concentrated on specific sectors or functions irrespective of the industrial field. Present studies have not paid sufficient attention to particular operations or functions in specific fields of manufacturing. Thus, there is a need for more specific investigation. Network research has commonly concentrated on economic aspects or relationships and there has been little focus on product and process quality. Moreover, studies mostly separate the supply chain and network for different operations in the manufacturing chain, i.e., the network view is seen as concentrating on management, and the supply chain as concentrating on transport or distribution. This approach restricts observations between different functions of a network. Furthermore, if networks are divided into different categorizes (e.g. entrepreneur, social and business activity [34]) it prevents development of a panoramic view of the whole manufacturing business.

When considering welding networks, empirical observations in this study have shown that more functions are focused on developing operations than promoting inter-function activity. At present, typical welding networks seem to have more the characteristics of a supply chain with focal company dominance than wider view network aspects (Fig. 3). The focal company dominates the transmission of demands of manufacturing. Harnessing the power of relationships and increased cooperation activity would enable emphasis on manufacturing throughout the production chain. Recent thinking on network behavior in manufacturing is bringing welding closer to dominant functions with a prospect of affecting the demands and quality of welding and at an earlier stage.

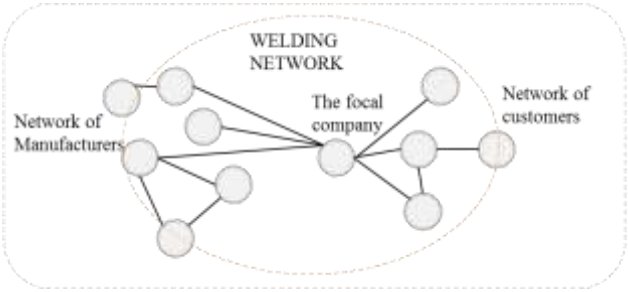

Fig. 3 Structure of a welding network with focal company dominance

As can be noticed, the dividing line between supply chains and networks is unclear from the manufacturing viewpoint and as a result supply chains and supply chain networks can be treated as networks, if the premise of the research is network studies, although differences in definition and variability in use of terms can lead to some uncertainty.

3. Linkages of welding networks

A typical supply chain in the welding industry is a welding supply chain in which the focal company is the dominant part of the chain and relationships between the focal company and one individual supplier are more common than relationships between suppliers or at multi-tiered levels. While the influence of different actions and relationships on network definitions is receiving more attention, the precise form of typical welding networks is still under discussion and requires closer observation. Observation and analysis of existing network models can be implemented in study of welding networks but there is no demonstration of the influence and behavior of different functions of welding and how to model functions under welding demands.

Profitable manufacturing is strongly dependent on fluent material flow and manufacturing competence. Furthermore as noted earlier, cooperation between different parts of a network and different internodal relationships are major influences in functional networks and effective management of production. A closer look at the linkages of networks is essential when looking at ways to improve business management [28]. The dynamics of everyday work is of importance and consequently the focus should be more on networking than observing the network [35] which emphasizes the importance of relationships between different functions of a network.

On the basis of previous research and in view of the lack of empirical studies focusing specifically on the field, welding, which is an established technology and a commonly undervalued action as manufacturing function in the manufacturing chain, is a subject of considerable interest. Welding manufacturing has the potential to enhance network profitability through the development of relationships, competences and functions. Consideration of welding operations as part of an effective and cost-effective manufacturing chain can bring a considerable increase in profitability [36].

The linkages of a network can be observed in different ways depending on the viewpoint chosen. Internal linkages, e.g. between production, marketing, purchasing and logistics functions, and external linkages, e.g., between retailers, manufacturers and suppliers [27], can be viewed differently when seen from the point of view of a focal firm at the upstream level, at the focal firm level and at the downstream level. In a network, the focal firm has a better network position relative to the downstream firms [12]. By setting the upstream level as suppliers and the downstream level as customers, the observation level is defined as the focal firm (Fig. 4). This simplified structure is outlined picture with welding workshop manufacturing.

With focal firm dominance a number of predominant functions determine the profitability of the welding

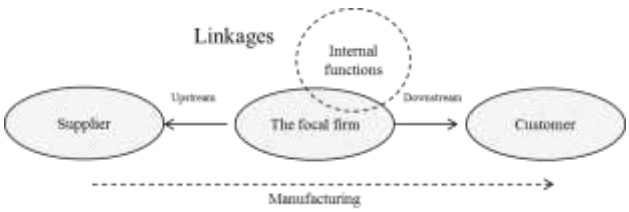

Fig. 4 Simplified structure of linkages of a welding network

network. The internal costs of the focal company and the area of responsibility of each function dictate the manufacturing costs and can affect optimizing functions at others' expense. Increasing the profitability of a welding network requires knowledge of the internal linkages and knowledge of network control. Design, purchasing and welding engineering within quality functions and logistics affect welding actions before, during and after actual welding and have an impact on the costs of manufacturing in the welding network. Coordination of welding is linking the functions together with responsibility of welding operations.

These main functions need the support of management to implement decisions regarding issues of welding manufacturing with a focus on the quality of welding and product and manufacturing requirements (Fig. 5). The welding requirements add complexity to ensuring the quality of welded products when there are many cooperative manufacturers in the welding network. Thus, welding networks with special demands, like the environmental demands of Arctic and offshore manufacturing, and the high safety demands involved in welding of pressure vessels and in the nuclear industry, need to observe particular responses and relationships. There is also need for understanding of the different relationships affecting the companies in the network structure even when no direct link exists [37].

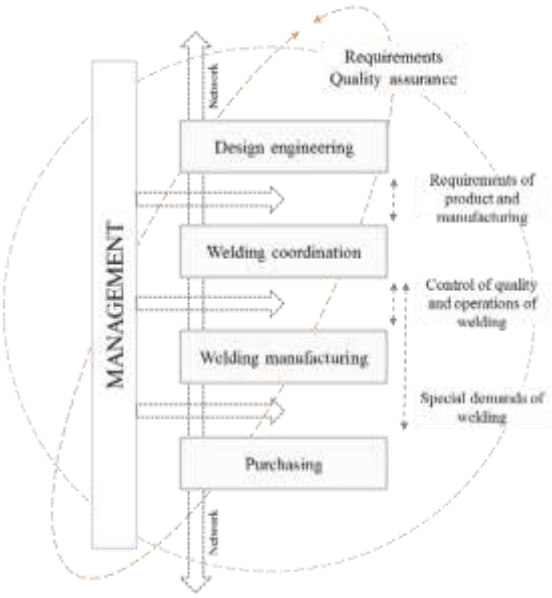

Fig. 5 Links between different functions of a company

Network quality is a significant concern when aiming to achieve competitive advantage [38] and when manufacturers expect continuous improvement of network members' performance [39]. When firms improve interaction with suppliers and with customers on issues related to materials flow and quality, firms can expect better time-related operational performances as delivery speed and punctuality [40]. In networks with focal firm dominance, the responsibility for assurance of the quality requirements rests with the focal company.

4. An example of a welding network

An example case welding network and its behavior was studied empirically through observation and information from data collection. The example network structure and its linkages discussed here consists of three different welding networks with focal companies and six first tier welding cooperation companies with focal company dominance. In this specific configuration, one individual firm is bound to have cooperation with two networks. These structures would widen if dominance in different aspects of linkages and cooperation is considered. More tiers are connected through the first tier.

The data was collected through multiple interviews, observation of focal companies and network members, and written interview study. The target group comprised welding coordinators and design engineers, purchasing operations, specialists of quality functions and welders.

Fig. 6 presents the structure of the three welding networks studied. The three different entities include customer networks, which are not discussed in this study; the focus is on linkages and cooperation of the focal company (in the middle) and suppliers (within the network). The tier level of the network was dictated by the welded product and different welding phases. Only welding functions were observed. Part of the manufacturing chain was beyond the focus area of the network and only a few main welding suppliers were studied in this structure.

Each different network has linkages to other firms. These connections describe the chain of welding manufacturing, and as can be seen, the direction of manufacturing is towards the focal firm. The direction of intercommunication is mainly two-way in the first tier of the chain. This indicates the importance of cooperation in manufacturing of welded products. If the tier level rises, it seem that intercommunication with the focal company becomes non-existent, which can affect quality assurance.

The cooperation level can be observed also from the communication patterns of different functions at the internal network level. A lack of internal information transfer and a need for greater cooperation between welding engineering, design engineering and purchasing functions can be seen. Normally, the quality department is a part of or close to the welding functions and cooperation is at an appropriate level. However, this cooperation is too often restricted to handling deviations or assurance of quality requirements in internal manufacturing.

Logistic with information transfer has minor effect compared to intercommunication and cooperation in order to develop welding manufacturing. Transport logistics is mainly outsourced and rarely has any significant influence on the welded product even if the manufacturing chain extends globally. This position requires systematic transport logistic design with applicability on particular welded products and when there is no special demands on transporting.

Cooperation between internal functions of the focal firm and other network members depends on company culture and the quality level of the welding functions in the focal firm. However, it is notable that purchasing and quality departments are closely bound with cooperation companies, and more remarkable is that the cooperation mainly consists of handling defects and complaints with suppliers. Quality assurance by the focal firm is irregular, either centered on the start of the cooperation or a subject of periodic control. The example welding network studied shows the enormous potential for improvements to the efficiency and profitability of welding networks.

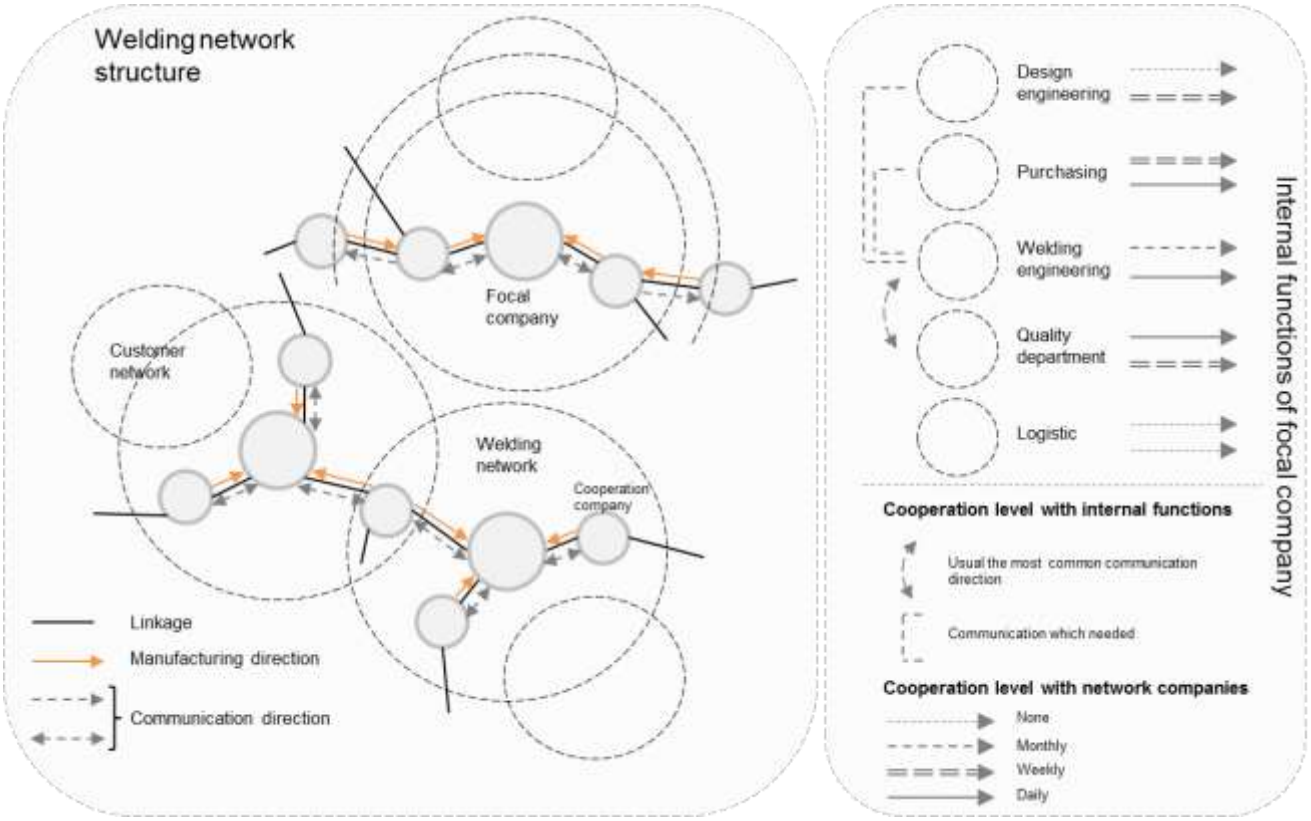

Fig. 6 Example of a welding network with linkages and cooperation level of internal functions and network

Improvements in the cooperation level and assurance requirements of the welding will be reflected in the quality and cost of the end product.

5. Conclusions

Welding manufacturing can potentially improve profitability by developing networks with appropriate relationships, competences and functions. The research in this work indicates that a lack of communication in internal functions within the focal company dominating the welding network can reduce efficiency and prospects of increasing profitability of welding manufacturing, and thus end product profit. This research has resulted in new insights into the changing business environment in welding manufacturing, welding network structure, and relationships of network members. The example draws attention to linkages of the welding network and potential for improvement.

There is a lack of research about welding networks and the cooperation level between linkages of network members, although linkages are clearly important in network behavior. Our example of a three welding network structure with multiple linkages shows that the direction of intercommunication is mainly mutual in the first tier of the chain, which demonstrates the importance of cooperation in manufacturing of welded products. However, when the tier level rises, intercommunication with the focal company partly breaks. It is also noted that the most common form of cooperation between the focal company and other network member deals more with defects and reclamations than quality assurance and welding coordination. This finding indicates a lack of internal information transfer and the need for more cooperation both internally and externally in order to achieve more development of manufacturing cooperation and profitability.

Welding networks have enormous potential to increase the profitability of production through effective management of internal cooperation linkages with design engineering, purchasing, welding coordination and welding manufacturing, and by focusing external cooperation on quality assurance and welding requirements. Transport logistics is mainly outsourced and rarely has any significant influence on the welded product even if the manufacturing chain extends globally. This position occurs when there exist systematic suitable logistic design on manufacturing for particular welded products.

Previous research on networks lacks empirical studies and the particular field of welding networks requires specific research. Future research is needed to study further the management of welding networks, such as the effect of linkages in welding networks and the cost-effect on the profitability of welding manufacturing of deficiencies in cooperation. The value of networks and their effect on the quality of welding manufacturing, including component manufacturing, welding, finishing and painting, and other manufacturing functions, and thus the profitability of the final product is an interesting aspect requiring further research. There is also need for observation of welding networks with special requirements, like welding for the offshore, pressure vessel, nuclear and Arctic industries.

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FROM SUPPLY CHAIN TO WELDING NETWORK: A FRAMEWORK OF THE PROSPECTS OF NETWORKS IN WELDING

S u m m a r y

This research has resulted in new insights into the changing business environment in welding manufacturing and welding network structure. It thus contributes to partly addressing the lack of network research within specific fields of network manufacturing, like welding, and research considering cooperation levels with linkages of network members. The study is based on theoretical insights into networks presented in the literature and empirical knowledge of the welding and manufacturing industry. An example provides evidence of the linkages of welding networks and areas that can potentially improve the profitability of manufacturing and the end product. It is found that the cooperation level in welding manufacturing is insufficiently developed for optimal network prospects and profitable network manufacturing. Additionally, the need for specific research of welding network management and their influence on improved quality and profitability throughout the manufacturing chain is noted.

Keywords: manufacturing network, network management, welding linkages, welding network, welding supply chain.

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