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Demand Variability in Supply Chains: The Influence of Global developments and Globalization on the Local Dutch Steel Industry

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THIS PAPER IS A DRAFT VERSION PREPARED FOR THE 1\textsuperscript{ST} ANNUAL MSM RESEARCH CONFERENCE, 11-12 NOVEMBER 2011 – IT IS INTENDED FOR DISCUSSION PURPOSES ONLY
Abstract
For many decades the steel industry has developed on a slow but steady pace. Since 2004 the developing economies in Eastern Europe, Asia and South America radically influenced this situation. The growth in these regions was an important cause of shortages in raw material and resulting price fluctuations. Other aspects were improved logistics, speculation and the creation of global multinationals in the steel and mining industries.

The local Dutch steel market evolved differently. In recent years, the market volume has shown a slow but steady decline as a result of economic, social and demographic factors as well as outsourcing and off shoring. As a result, local competition increased, causing pressure on operational margins and increasing financial risks. The current increased demand variability has a negative impact on these effects.

This study aims to identify the causes and the consequences of the variability in demand that has been experienced by the Dutch steel sector. The study focuses on steel sheets and sections (beams); products which are used in different markets. Steel construction companies (SCCs) purchase steel sections for uniquely designed building projects. Steel sheet processing companies (SSPCs) are process orientated and supply a wide range of industries, often on the basis of medium term contracts. This orientation provides them with the options to hold stocks, in sharp contracts to steel companies operating in the construction sector. Second, this study aims to find solutions for the supply chain to mitigate the negative consequences of demand fluctuations.

Secondary company data was analyzed to establish to what extent variability of demand in the Dutch supply chain of steel sheets and sections exists. By using a survey, the consequences for the Dutch steel sector were quantified for SCCs and SSPCs. The study identified the causes of the variability of demand by conducting a survey among a group of SCCs and SSPCs and by comparing demand data to both local and global market indicators. Finally, possible solutions were discussed with steel processors by means op in-depth unstructured interviews.

The study confirms that different echelons in the supply chain inflict different levels of demand variability on their upstream suppliers. SCCs and SSPCs increase variability demand significantly, while steel distributors facilitate a smoother demand pattern for steel mills, a phenomenon known as the reversed bullwhip effect.

The most important factor that influences the level of variability of demand is (expected) price fluctuations, followed by batch ordering. Price fluctuations are identified to be largely dependent on global factors. To a lesser extent they are related to local economic development. Therefore we can conclude a direct influence of global developments and globalisation on the local Dutch stele sector exists.
1. INTRODUCTION; AN OVERVIEW

After a long period of relative stability, the global steel industry has undergone significant changes since 2004. The economic growth of the emerging economies of East Asia and South America resulted in global shortages and price rises for many raw materials, energy, labour and logistical services. Mining companies and steel mills expanded their capacities. China became the dominant producer, increasing its share from 13% to more than 50% of world steel output (CRU, AM Fact book 2009). Increased options for transportation created a global market for raw materials. Through a process of mergers and acquisitions, large multinationals came into being. In 2002, the top 3 mining corporations had a market share of 33%. Today, they account for 71% of global mining activities (AT Kearny, 2007). Globalization of the steel market has become a dominant driver that caused a sharp increase in variability of demand and price levels.

The current situation in the Western European steel supply chain is in sharp contrast to the global market. Demographic factors, insufficient adjustment to globalization and the recent economic crisis caused a steady decline in building and construction activities. Outsourcing and off shoring to low cost countries had a negative impact on local industrial production. In the next years, a further decline in growth rates is to be expected. The steel supply chain is currently in a transition phase, as it needs to reduce capacity and adapt to changes in customer demands; flexibility, higher levels of technology and sustainability. Today, steel distributors face an unfavourable combination of fierce competition and high risks caused by demand and price volatility.

Destocking, overstocking, dumping and speculative purchases occur in local markets and increase globally initiated fluctuations in demand and price. Steel processors try to fix prices at the lowest possible levels, or engage in renegotiations. This leads to increased pressure on the operational margins of distributors. Variability in demand results in a number of other unfavourable consequences. Processing and distribution capacity occupancy as well as capital requirements and financial ratios fluctuate sharply. Depreciation is a common phenomenon; six months after the recent economic crisis set in, leading European steel distributor Klöckner & Co. announced its inventory
value had decreased by €600 million (Source: Steel Business Briefing). Demand forecasting becomes less accurate. Safety levels increase or, stock service levels decrease, causing extra expenditures for additional on-the-spot purchases. Competition between steel distributors intensifies as customers cannot rely on the services of a single supplier. A final undesirable consequence is an increased vulnerability of the Dutch steel processing sector as it is exposed to similar market conditions.

This study will investigate the causes of recent demand variability in the Dutch supply chains of steel sheets and steel sections (beams). Steel sheets are utilized as input material for many different applications in industrial production processes. Steel sheet processing companies (SSPCs) are process orientated and hold inventories. Steel sections are used as input material for construction related applications. Steel construction companies (SCCs) are project orientated. The majority of SCCs order just-in-time and generally hold no inventories. The different orientation of both sectors can help to create an understanding of the dynamics of variability.

As a direct result steel demand and steel prices have, after many decades of stability, shown drastic fluctuations. Multiple causes for this sudden change can be identified. The economic growth in China, India, Brazil and other countries has been a main driver. Consolidations of mining companies and (to a lesser extent) steel mills, temporary shortages in raw material supplies, fluctuations in transportation costs and the introduction of steel future contracts have also contributed to these fluctuations. These effects were experienced in steel markets worldwide; both in growth and mature markets, such as the EU15 countries.

Many European industrial sectors have been under pressure in recent years. In these sectors price competition is especially fierce under conditions that provide only limited options to add value to output. Examples of industries that experienced these conditions are the mining, textile fabrications and shipbuilding industries. Due to the severe structural productivity problems in the EU15 countries and the insufficient adjustment to globalization a permanent and significant decline in potential growth rates is to be expected (Carone et al. 2006). Similar conditions apply to the Dutch steel construction and steel sheet processing industries. The Dutch construction sector will
be hampered by a decline in future demand. No structural recovery is to be expected in the coming years (TNO/Dutch Ministry of Housing and Planning, 2009). The steel sheet processing sector has a slightly better outlook but is also under pressure due to generally lower demand and competition, mainly from low-cost countries (ING Bank; Dutch Manufacturing 2010).

In the steel sector, demand and price variability are not only affected by global and/or cost developments, but also by local market mechanisms. Destocking and overstocking are commonly observed phenomena and distributors target other market segments as their markets become saturated. Variability of demand can have unfavourable consequences:

- Decreasing service levels, leading to extra expenditures for additional on-the-spot purchases, increasing of (safety) stock levels
- Fluctuating occupancy of processing and distribution capacity
- Added pressure on operational margins and increased risks
- Fluctuating financial ratios and capital requirements
- Decreasing accuracy in demand forecasting

The existence of the problem is confirmed by the analysis of company data from a leading Dutch steel distributor over the years 2002-2010 as well as cross-sectional information based on expert opinions from executives in the steel distribution market. The literature review revealed considerable research has been undertaken in the area of demand fluctuations. The common ways in which the problem has been examined include the application of general economic principles to commodity good markets, adopting an approach based on the (mainly theoretical) price elasticity of demand and the (often mathematical) approach of the bullwhip effect in supply chain. The review did not reveal a holistic vision of the existence of demand variability in the steel industry and its relationship to these factors.

1.1 Causes of demand variability in the supply chain

The existing literature reveals three different areas from which causes arise. First, evidence shows that global economic and business developments and incidents have a major influence on demand variability upstream in the supply chain and on consequential price levels throughout the supply chain. In respect of industrial
commodity products, demand is determined by local competition and end-user demand for a range of final products. In our case these include products such as warehouses, transport equipment, housing, bridges and machinery. End-user demand is thus mainly determined by local conditions in industrial sectors.

Second, economic factors outside the immediate supply chain cause demand and price to vary. Price elasticity of demand, volatility of commodity prices and business cycles are identified as important indicators of this influence. Third, evidence is found that variability is caused within the supply chain itself. The prevailing researched and documented theory on this subject is that of the bullwhip effect. It provides both an understanding of the factors that increase variability as well as the solutions which reduce the effects. The identified causes of the bullwhip effect are; demand forecasting, lead times, rationing and shortage gaming, batch ordering and price expectations. Production smoothing was identified as highly debated but utilized method to moderate the impact of demand variability by achieving a constant use of production capacity. Figure 1 is a modelled view of the factors that were identified in the literature review and their relationships.

![Diagram of the theoretical framework](source: author)
2. THE GLOBAL STEEL INDUSTRY

Steel is one of the most important input materials for many industry sectors. Steel fabrication is a capital intensive mass production process using iron ore and coal or scrap and electricity as input. The importance of labour as a production factor is declining. Steel sections (the commonly used term for steel H-, U- and I-beams) and sheets are both producers’ goods, meaning their demand is derived from the consumers’ demand for the finished products in which they are used as raw material (McGuigan et al. 2005). Steel sections are mostly used for the construction of industrial buildings such as warehouses, plants and factories. Other applications are machine frames, warehouse equipment and staircases. Steel sheets have a much wider scope of use. Target markets for steel distributors include shipbuilders, original equipment manufacturers, transport and agricultural equipment manufacturers, white and brown good producers, parts suppliers and the machinery industry. Thus steel demand for sheets and sections depends on developments in the building sector and a wide range of other industrial sectors.

From the Second World War until the early years of the 21st century, the steel market was fairly stable and enjoyed a steady but slow growth. Trade barriers were common as many countries protected their steel industry because of its strategic importance and role of big employer. However, periods with significant changes occurred. Between 1960 and 1974 the world steel consumption doubled and subsequently decelerated until 1982 (www.economywatch.com).

2.1 Recent developments in the global steel industry

In recent years, two important developments took place in the steel industry. Traditionally country members of the Organization for Economic Cooperation and Development (OECD) were the biggest steel producers. In the last decade, the emerging economies of South Korea, India and China turned these countries into important producers and consumers of steel. As shown in table 1, Chinese steel production has sharply increased; from 13% in 1995 to around 50% today. Nevertheless, due to its massive national consumption, China remains overall a net steel importer. During the recent economic crisis, the steel industries in the developed
countries were hit hard and production output decreased dramatically. This has accelerated the dominance of China in becoming the largest producer in the world.

<table>
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<tr>
<td>Europe</td>
<td>163</td>
<td>166</td>
<td>173</td>
<td>183</td>
<td>178</td>
<td>200</td>
<td>204</td>
<td>186</td>
<td>137</td>
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<tr>
<td>USA &amp; Canada</td>
<td>109</td>
<td>111</td>
<td>111</td>
<td>124</td>
<td>109</td>
<td>119</td>
<td>111</td>
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<td>Japan</td>
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<td>94</td>
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<tr>
<td>South Korea</td>
<td>44</td>
<td>48</td>
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<td>63</td>
<td>67</td>
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<tr>
<td>China</td>
<td>148</td>
<td>181</td>
<td>221</td>
<td>257</td>
<td>318</td>
<td>383</td>
<td>455</td>
<td>476</td>
<td>596</td>
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<tr>
<td>CIS</td>
<td>38</td>
<td>36</td>
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<tr>
<td>World</td>
<td>738</td>
<td>793</td>
<td>863</td>
<td>943</td>
<td>993</td>
<td>1.109</td>
<td>1.221</td>
<td>1.224</td>
<td>1.184</td>
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Table 1: Crude steel output by country/region (sources: CRU, AM Fact book 2009)

The second important trend is the globalization of the steel industry. The impact of this development can hardly be overstated. It has had more impact on the European steel market then any other recent development. Focus on the causes will provide both a good understanding of the current factors that determine price and demand in the steel industry as well as a clear picture of characteristics of the industry itself. Important drivers for globalization are:

1. Increased options for global transportation of bulk goods

Due to economical, market, technical and infrastructural developments shipping ore, cokes, steel and finished product worldwide became a real and economically feasible option for the industry. Though prices rebounded since 2005, improved options for transport are still a major driver for the globalization of the steel industry. Today, according to data by global mining market leader BHP Billiton, 55% of South American iron ore production is sold in East Asia and 12% in Europe. The world biggest producer of iron ore, Australia ships more than 97% of its output to Asia. According to steel research agency ISSB, in 2009, 419 million tons of steel was exported, accounting for 34% of world production.
2. Mergers and takeovers created multinational mining and steel corporations

According to the AT Kearny Merger Endgame theory, the consolidation trend is divided into 4 steps: opening, scale, focus and endgame. Increased consumption, technology availability, rising globalization and resource scarcity are identified as major drivers. The study reveals that the mining industry is the world’s most advanced sector in the global M&A process. In 2002, the top 3 mining companies accounted for 33% of world production; in 2009 they account for 71%. In this period the turnover of market leader BHP Billiton increased from $44 to $172 billion (Source: AT Kearny, 2007).

Today steel production is still in the second phase of the M&A process. It came in full swing in the early 2000’s. Consolidation among steel producers reached its peak in 2006, when the top 3 producers accounted for 185 million tons. This equaled 18% of total production, compared to 11% in 2002. The most significant growth has been achieved by ArcelorMittal which increased its output from 44 ton 116 million tons of steel in 2006 (World Steel Association, 2009). The economic crisis in developed countries led to a decrease in market and available capital among the largest producers; the consolidation process came to a factual standstill.

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<tr>
<td>ArcelorMittal</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>116</td>
<td>103(1)</td>
<td>78(1)</td>
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<tr>
<td>Baosteel</td>
<td>-</td>
<td>-</td>
<td>8(20)</td>
<td>17(5)</td>
<td>23(4)</td>
<td>29(6)</td>
<td>35(3)</td>
<td>31(2)</td>
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<tr>
<td>Posco</td>
<td>-</td>
<td>15(3)</td>
<td>23(2)</td>
<td>28(2)</td>
<td>31(4)</td>
<td>31(5)</td>
<td>35(4)</td>
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<tr>
<td>ThyssenKrupp</td>
<td>12(5)</td>
<td>12(8)</td>
<td>10(12)</td>
<td>17(7)</td>
<td>16(11)</td>
<td>17(18)</td>
<td>16(20)</td>
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<td>BS/ Corus/TATA</td>
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<td>18(8)</td>
<td>26(7)</td>
<td>24(8)</td>
<td>20(7)</td>
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Table 2: Largest steel producers (source: World Steel Association, 2010)

The Herfindahl index indicates the level of consolidation and the relative size of individual corporations in a market by measuring the sum of the squares of the market shares of each individual firm). Today, it stands around 1.300. This is an indication that the level of concentration in the steel sector is low to moderate (Source: EU Directorate-General Enterprise & Industry: Study on the Competitiveness of the European Steel Sector, 2008).
3. **Large infrastructural and oil & gas projects in developing countries**

These projects require the input of worldwide production capacity. They are indentified as major drivers by the online economist community Economy Watch ([www.economywatch.com](http://www.economywatch.com)). Among major projects on the Schiller Institute list are the Sakhalin-Vladivostok Pipeline in Russia, the Trans Aqua project in the Maghreb, the Beijing-Tibet railway and the Eurasian land bridge ([www.schillerinstitute.org/economy/maps/maps.html](http://www.schillerinstitute.org/economy/maps/maps.html)).

4. **The adoption of liberalization policies and its impact on the reduction of trade barriers** ([www.economywatch.com](http://www.economywatch.com))

According to Economy Watch, trade barriers have been significantly reduced in recent years. However, other sources claim they still have a major impact on the global steel industry. The 2009 OECD report “Export Barriers and Global Trade in Raw Materials: The Steel Industry Experience” concludes: “Currently, trade in these raw materials is not free, with major producers imposing a variety of restrictions on exports. These restrictions drive up global prices, increase price volatility, and give domestic producers in the countries with export restrictions an artificial advantage in international competition. In this way, export restrictions distort not only the world markets for these raw materials, but the broader world markets for steel and for product made from steel.”

5. **Consolidation in customer markets increased demand for globally operating suppliers**

Today, many important markets are dominated by multinationals. Mitsubishi is such an example; a major steel consuming company with a global presence in construction, machinery, automobile, metal products, mining and transport equipment markets.

Other drivers of globalization are recent investments in state-of-the-art production capacity in emerging countries which have raised are the general quality level of steel,
the increased availability of market information, improved communication techniques and outsourcing of production to low cost countries.

2.2 The consequences of globalization

Globalization has had a major impact on the steel supply chain. It has created a market in which local conditions no longer form the basic components that determine price levels, lead times and availability. Prices are now determined by growth regions like China and India: “…the world metal price rose by 180 per cent and of energy by 170 per cent, according to Goodman Sachs, in good part because of China’s demand.”(Financial Times, January 23, 2008), and global events: “The recent floods in Queensland Australia are already inflating prices of coking coal and restricting availability. The disruptions in supply drove coking coal spot prices up by USD 40-50 a ton.”(The Economic Times, February 2\textsuperscript{nd}, 2011). The same influence applies to raw materials markets.

The ABNAMRO Sector Research Report 2010 states: “Because steel is traded globally and China accounts for approximately 45% of global steel production, the development of steel prices in China have a high influence on the global HRC price.” The same influence applies to the raw materials markets. The graphs below show the correlation between prices of scrap, iron ore and finished steel. Price rises in raw materials are absorbed in the price of steel some 2 months later.
Figure 2: The correlation between raw materials scrap/iron ore (left) and steel prices (right)

(Sources: Steel Business Briefing/Gerdau and US Department of Labour, Bureau of Labour Statistics)

This view is confirmed by the following table showing the German price level of both steel sheets and sections. Although the fluctuations in price bear relevance to the overall economic growth, price developments are much more correlated to the world markets of steel related commodities.

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<tr>
<th>€/t.</th>
<th>2000</th>
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<td>HR Coil</td>
<td>317</td>
<td>258</td>
<td>276</td>
<td>309</td>
<td>443</td>
<td>450</td>
<td>464</td>
<td>488</td>
<td>630</td>
<td>420</td>
</tr>
<tr>
<td>Change y/y</td>
<td>-7%</td>
<td>-9%</td>
<td>7%</td>
<td>12%</td>
<td>43%</td>
<td>2%</td>
<td>3%</td>
<td>5%</td>
<td>29%</td>
<td>-33%</td>
</tr>
<tr>
<td>Sections</td>
<td>315</td>
<td>310</td>
<td>318</td>
<td>350</td>
<td>495</td>
<td>509</td>
<td>552</td>
<td>658</td>
<td>818</td>
<td>525</td>
</tr>
<tr>
<td>Change y/y</td>
<td>-5%</td>
<td>-2%</td>
<td>3%</td>
<td>10%</td>
<td>41%</td>
<td>3%</td>
<td>8%</td>
<td>19%</td>
<td>24%</td>
<td>-36%</td>
</tr>
</tbody>
</table>

Table 2: German coil and section prices 2000-2009 (Sources: CRU, TEX report, Metal Bulletin and ArcelorMittal estimates, AM Factbook 2009)
2.3 The Dutch steel construction and sheet processing markets

Steel construction companies (SCCs) specialize in processing (welding, cutting, sawing, drilling and surface treatment) and assembling steel sections. Despite having optimized these processes in recent years, the sector still has a traditional character and little innovation occurs. The steel construction sector is considered by CBS (the Dutch Central Statistics Bureau) a very important part of the national economy. According to a recent ING Bank study (2007), the value of steel products supplied to the Dutch building sector was just under €3 billion per year, achieved by 1,500 companies with 37,000 employees. This accounts for around 20% of the total output of the total Dutch steel industry.

SCCs are highly project orientated. Typically, the length of building projects varies between 6 and 24 months. Steel constructors are generally hired as subcontractors, pre-financing and building the steel construction. Prices are usually set in advance. The prevalent risk of price fluctuations and their influence on margins is a threat for the profitability of SCCs. The project orientation leads to fluctuations in the workload. Adding to this concern is the need for steel constructors to ensure a steady and sufficient inflow of work in order to keep their production capacity filled. Efficient production and economics of scale and high investments in production capacity put pressure on filling capacity, further increasing the risks. The third cause for concern is the relative size of SCCs compared to their suppliers and customers. Consolidation is not a trend for SCCs in contrast to the contracting and distribution sectors.

ABN AMRO states on the current economic climate for the construction sector: “The production of residential and commercial properties will show no significant recovery in 2011. A fragile recovery of the economy and uncertainty in the market still has a pressing effect on demand for new construction. In addition, the number of maintenance projects will decline in 2011. Local governments lack financial strength as a result of declining revenue from housing land development. Therefore, the economic conditions for construction in 2011 are expected to remain weak (ABN AMRO Sector Economic Perspectives, Q3, 2010).

Steel sheet processing companies (SSPCs) supply to a much wider scope of industries. Sheets require a much more diversified number of processing techniques such as laser
welding and cutting and 3-dimensional designing. This is reflected in many recent technical innovations in input material. New qualities for special application have been developed by steel mills. SSPCs optimize processes by implementing technical and organizational innovations. Mainly due to a steady decrease in volume and order size and the influence of low-cost production countries, SSPCs are much more focused on increasing flexibility, on becoming a supplier of systems and finished products and on vertical integration in the supply chain (ING, Dutch Manufacturing Report, 2010).

According to ABN AMRO, the sector has a reasonably good economic perspective; “Thereby, the economic outlook for the Netherlands and its main export countries are relatively favourable. Recovery is still fragile, but based on the expected economic growth, many modes should benefit (ABN AMRO Sector Economic Perspectives, Q3, 2010).”

The Dutch steel distributors earn their place in the steel supply chain because only they are capable of transforming the irregular and volume orientated output of steel mills into a customized offer to smaller and medium sized steel processors. Distributors have a wide product range, processing facilities and logistics and transportation services. Steel is typically delivered on a just-in-time basis. Supplying steel is highly capital intensive for stockholders because of the requirement to have adequate stocks in many sizes, lengths and qualities, in combination with the relatively high and fluctuating cost of steel. Keeping inventories low, maximizing stock turnover rate, minimizing working capital and creating efficient operations are essential to keep business profitable. Dutch stockholders are independent or integrated. Independent stockholders enjoy the freedom to obtain sections from any supplier, but they could lack the support of steel mills. Integrated stockholders are part of steel producing multinationals and enjoy the advantages of better availability, first-hand information and project support.

3. VARIABILITY OF DEMAND AND PRICE OF COMMODITY GOODS

Price variability of commodity goods has a negative impact on economic growth (Van Duyne, 1979; Labys and Maizels, 1990; Dehn, 2000). Also variability in price and
demand - especially of commodity goods - is often indicated as an economic factor of major importance which can lead to changes in employment, output - including economic cycles - and changing conditions in money supply, interest and exchange rates. Maizels (1987) underlines the importance of the commodity markets as a potential source of economic instability; ‘the commodity sector has come increasingly to operate not only as a mechanism for the transmission of recession from the developed or industrial countries to peripheral economies, but it has also become a major source of instability in the world economy as a whole.’ Many commodity prices have a forward-looking element and are determined in auction markets. These markets respond quickly to changes in supply and demand - in contrast to prices in consumer markets for manufactured goods. This adds to their influence on economic development (Bosworth and Lawrence, 1982, Beckerman and Jenkinson 1986). Dehn (2000) identifies price shocks and price uncertainty as having a significant influence on economic growth rates. According to Dehn, the magnitude of the effect of negative shocks on growth is substantial. Negative shocks seem to have no correlation to investment levels. This is an indication that timely adjustments can be achieved by restraining existing utilization of production capacity. Positive shocks often lead to inflation; prices are not adapted after up cycles. Minerals are identified by Labys and Maizels (1990) to have a larger influence than agricultural products due to the ability to be stored for longer periods.

In his classic work “Das Kapital“, Karl Marx (1894) emphasized the consequences of price fluctuations on the rate of profit; “But in general, it should be noted here (...), that if variations take place, either due to savings in constant capital, or due to fluctuations in the price of raw materials, they always affect the rate of profit...” This influence depends on the ability of the individual firm to adapt sales prices to changing levels of costs; “... that the price of the product does not rise in proportion to that of the raw material, and that it does not fall in proportion to that of the raw material. Consequently, the rate of profit falls lower in one instance, and rises higher in the other than would have been the case if products were sold at their value.” Thus we can conclude that the consequences of demand and price variability also apply for individual companies.
3.1 Demand and price dynamics in the steel supply chain

The ABNAMRO Sector Research Report (Q2, 2010) acknowledges the influence of raw materials price levels on the price of steel. It concludes the behaviour of the input prices of steelmaking raw materials are the key factor in the development of steel price. The influence of volatility in raw materials on steel prices increased when the pricing mechanism of both iron ore and coking coal changed from yearly to quarterly pricing, where the price is based on the average spot price of the three months prior. As a result, steel prices became more volatile and steel mills were forced to negotiate steel price with end users on a more frequent basis.

Sharma (2010) confirms that the steel industry around the world has been faced with price volatility over different periods of time. This has been placed as an added pressure on the production and consumption of steel.

In 2009 the London Metal Exchange (LME) launched the first steel futures contract. The LME claims trading steel via future contracts acts as an institutional mechanism of risk management creating a stabilizing effect on the world steel market. Sharma (2010) however concludes the opposite. Similar commodity markets (aluminium and oil) have shown an increased volatility after the introduction of future contracts. He claims contracts will not lead to speculation in the form of ‘rational behaviour’ (e.g. hedging) but to gain profits in the form of risk premiums. He argues that especially in emerging markets, a futures trading mechanism might hamper growth. His findings are backed by Feingold who states; “...the hedge funds and financiers are trying to suck whole new areas into the whirlpool of commodities speculation, including, now, world steel production”. (Executive Intelligence Review, July 7, 2006) In similar fashion, Lakshmi N. Mittal, CEO of ArcelorMittal, commented a few months later; "I don’t think we need a futures market for steel". (Executive Intelligence Review, July 7, 2006)

From an economics viewpoint, business cycles refer to periods of expansion and recession in the level of economic activities (Burns and Mitchell, 1950). Many sources confirm the steel industry is a cyclical industry, i.e. it shows a more than average cyclical pattern. Sectors related to industry, transport and automotive are usually early-cyclical, while the shipbuilding and construction sectors are regarded late-cyclical. The
recent economic crisis caused a decrease in building activities of 28% (housing sector) and 43% (industrial sector) in the Netherlands in 2009 (ING Bank, 2010).

3.2 Price elasticity of demand

The relationship between changes in price and demand is studied in the concept of elasticity. The price elasticity of demand refers to the response of demand to changes in price. The price elasticity of supply measures how much the supplied quantity responds to changes in price. According to Thompson (1926), price fluctuations are less apparent under elastic demand. Elastic demand causes a strong reaction to price fluctuations. Resulting increases or decreases in demand stabilize the price level, thus limiting fluctuations. McGuigan et al. (2005) define the relationship between a product’s price elasticity of demand and the marginal revenue at that point as one of the most important in managerial economics. The level of elasticity in the steel industry is determined by the market structure and a number of product/market characteristics (Mankiw and Taylor, 2006).

1. Market structure

Market structure is defined by taking four factors into account; the number and relative size of firms in the industry, the similarity of the products sold, the degree by which decision making is interdependent between firms and the conditions of entry and exit (McGuigan et al., 2005). When focussing on these factors, we noticed in section 2.2.4 that the number of suppliers (steel stockholders) in the Dutch steel market is relatively low. Steel sections and sheets are highly standardized in application, shape, size and quality. Product differentiation is very low. Suppliers try to differentiate in other aspects of their service: availability, logistics, customer relations, processing and stock programme. Nevertheless the degree of supplier differentiation is also relatively low. A notable degree of interdependence exists in the steel market as well as a strong focus on sales and stock volumes. Every action of a major supplier has a direct impact on the sales of its rival and provokes reactions. The volume of the steel market is slowly decreasing, fuelling fierce competition. The focus on market share (to maintain sufficient economics of scale) is strong and capital requirements to build up
inventories are high. These factors lead to relatively high entry barriers. Exit causes a limited financial risk but in practice it seems a no-go option for steel stockholders as they show a strong determination to survive even in the most difficult of times.

We can conclude that the steel section stockholder market is a pure and tight form of oligopoly. This is confirmed by Tian et al. (2005) who identify the overall market structure of the steel industry as being “close to the oligopolistic market.” Doz and Hamel (1998) state that oligarch firms have to face two sources of insecurity when making their decisions on pricing: unknown events in the future and the reaction of other competitors towards their actions and these events.

In an oligopoly, the demand curve is typically elastic above the market price (prices above the prevailing market level hardly generate demand). The point at which the demand curve suddenly changes into elastic is the prevailing market price. The shape of the demand curve is an important characteristic of any oligopoly: limited possibilities to pursue an individual market strategy. The transparency of the market competitors quickly adapt to strategies and prices of competitors; any action provokes a reaction. Achieving higher outputs at lower prices, adding value by increasing performance and making outstanding offerings is difficult to maintain on the long run. However McGuigan et al. (2005) emphasize it is difficult to define an individual firm’s demand curve because of the existing interdependence between firms.

2. Product/market characteristics

Product/market factors influence the level of elasticity of the demand curve. Lamb et al. (2010) identify a number of factors affecting the elasticity of demand. Sufficient availability of substitutes means customers can easily switch to other products. This makes demand more elastic. Steel sections and sheets are typically products for narrowly defined applications by specialized processors. Thus, the availability of substitutes is relatively low. Second, they conclude that demand will be more elastic when a good has a relatively high price in relation to a budget. The share of steel costs as part of the final product’s sales price is expected to be relatively high but variable in the steel
processing industry. It will be analysed as part of the research undertaken in chapter 4. Another important aspect influencing the level of elasticity is product durability; the more durable a product; the more elastic its demand because consumers can choose to repair or keep a product instead of replacing it. But steel processors do not have this choice; in a just-in-time production environment waiting is usually not an option as production needs to proceed. Although steel is highly durable, this aspect therefore strongly suggests a higher level of inelasticity. Also demand tends to be more price-inelastic at peak times – a feature that suppliers can take advantage of when setting higher prices. Finally a product’s other possible uses is relevant; as the number of uses increases, demand becomes more elastic.

<table>
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<tr>
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<th>Indication:</th>
<th>Creates:</th>
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<td></td>
<td></td>
<td>SPPC: variable</td>
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</tbody>
</table>

Table 3: Factors influencing price elasticity of demand in the steel supply chain (source: author)

3.2.1 Price elasticity of supply

The elasticity of supply depends on the ability of producers to quickly adapt their production levels to changes in demand. If supply is elastic, producers can increase output without a significant rise in cost or a time delay. If supply is inelastic, firms find it hard to change production in a given time period. Therefore it measures how scarce good are rationed between competing uses and how producers react to the incentive of a higher market price.
Suthikarnnarunai et al. (2009) conclude the steel industry has a limited capacity for quick adaptations to changes in demand. Nevertheless production cuts have been an important instrument for Western European steel producers to create relative shortages to improve price levels. In general, sheet mills producing on the basis of iron ore and coke can only shut down blast furnaces over a prolonged period of time. This procedure takes time to execute and typically leads to cutting down production by at least 30%. As we already concluded in section 2.2.4, production on the basis of scrap (section) allows quicker and more fine-tuned adaptation to market circumstances.

Cutting production is a normal phenomenon, but refusing to do so is equally common: “China’s steel mills appear to be churning out steel more in a fight for market share than to meet buyer’s demands. The big state steel mills in particular are the most reluctant to cut production fearing they will lose market share to competitors, so instead they are cutting prices just as the third quarter contract iron ore prices rises hit the balance sheet, pushing up raw material costs.” (Thomson Reuters)

### 3.3 Variability of demand within the supply chain

The final part of the literature review focuses on demand variability occurring within the supply chain, mainly by examining the theory of ‘the bullwhip effect’.

In the 1980, companies focused on improving manufacturing efficiency by strategies such as just-in-time manufacturing, kanban and lean manufacturing. The possibilities for further improvements in this area declined in recent years. Consequently attention shifted towards more effective supply chain management as the next step to lower costs, increase profits and market share (Simchi-Levi et al., 2008). Cucchiella and Gastaldi (2006) notice a shifting of attention from internal to supply chain in striving for efficiency of manufacturing. Heng et al. (2005) conclude supply chain management influences the (economic) business cycle.

Challenges in the current field of supply chain management can be related to three observations; (1) supply chain strategies cannot be determined in isolation, (2) designing a supply chain with minimal system-wide costs and maximum service levels and (3) uncertainty and risk are a natural part of every supply chain. These risks have been increased by recent industry trends; outsourcing, lean production and off
shoring. Other factors that increase risks are matching uncertain supply and demand, inadequate forecasting and fluctuating inventory/back-order levels across the supply chain (Simchi-Levi et al., 2008).

Paik & Bagchi (2005) identify 4 interrelated but distinct flows in the supply chain; material, information, ownership and payment. All of these flows must be streamlined from manufacturer to end-user through the integration of key processes, which include planning, controlling and managing conflicting objectives, like commercial flexibility vs. efficient production (Simchi-Levi et al., 2008). Globalization further enhances the complexity and dynamics of the supply chain. In line with our findings on the global steel industry, we find evidence that global events such as the recent flooding in Queensland and the earthquake in Japan almost immediately affect many supply chains.

3.4 The bullwhip effect
Variability and distortion of demand is a well researched topic in the field of supply chain management. J.D. Forrester is regarded a pioneer. The author of ‘Industrial Dynamics, A Major Breakthrough for Decision Makers’ (1958), studied the amplification of demand which occurs travelling upstream in the supply chain by using computer simulation models. According to Forrester, this problem is caused by the existence of lead (delivery) times and the inaccuracy of forecasts. Later studies at Procter and Gamble focused on small changes in customer demand that create unusually big changes in order levels at the producer. Lee et al (1997B) focused their research on the causes and identified four factors causing what became to be known as the ‘bullwhip effect’. They state; “Distorted information from one end of a supply chain to the other can lead to tremendous inefficiencies: excessive inventory investment, poor customer service, lost revenues, misguided capacity plans, inactive transportation, and missed production schedules. How do exaggerated order swings occur? What can companies do to mitigate them?”

The theoretical model of the bullwhip effect consists of a qualitative and a quantitative approach. The qualitative approach tries to identify the different factors that contribute to an increase in variability in the supply chain as well as possible measures
to mitigate these consequences. The quantitative approach tries to improve insight by mathematically testing the relationships between different causes and the individual significance of each variable.

3.4.1 The reverse bullwhip effect
Rong et al. (2010) conclude in their study that in certain cases it is the wholesaler and not the manufacturer who see the largest variance of demand. This implies that part of the supply chain can smooth out bullwhip patterns, in other words; demand volatility is greater than supply volatility. This process is identified as the reverse bullwhip effect. This phenomenon is confirmed by Cachon et al. (2007) who identified the presence of the bullwhip effect to be the largest in the middle of the supply chain in 50% of the industries they researched.

3.5 Production smoothing
Cachon et al (2007) conclude many economists prefer to focus on production smoothing than on the bullwhip effect when framing discussions on supply chain volatility. An upstream manufacturer usually pursues smooth production. The preferable condition is a minimal variability in replenishment orders from downstream customers. Balakrishnan et al. (2004) emphasize dampening upstream demand variability as an opportunity to reduce supply chain costs. Cost advantages could be achieved due to factors such as the nature of the cost function or to purchase price advantages. If they outweigh increasing marginal costs and demand is relatively predictable, for example because of seasonality, such a strategy can be effective. In this respect, Boute et al. (2007) state; “..if production costs are convex, then it is optimal for a firm to only partially adjust output in response to a change in its inventory position.” Also they identify manufacturers as being the main benefactors from production smoothing. Retailers would prefer a replenishment policy based on actual customer demand. Both Cachon and Boute find considerable evidence in academic literature questioning the effectiveness of production smoothing strategies.

Production smoothing is not a well documented phenomenon in the steel supply chain, indicating it might not frequently be applied. Possible causes could be the
capital intensity of steel production, the made to order policy of steel mills and the irregular pattern of demand and price variability which increases the risks of production smoothing.

3.6 The causes of the bullwhip effect

Alony and Munoz (2007) state that the identification of causes for the bullwhip effect is difficult as most real world supply chains are not easy to study. Forrester (1958, 1961) attributed the cause to both irrational behaviour of participants in the supply chain and the absence of a holistic vision (e.g. an integrated view on the entire supply chain). After rigorous testing of the famous beer game, Sterman (1989) and Rong et al. (2006) confirm irrational behaviour as a major cause of the bullwhip effect; participants underestimated the ordering delays and did not take the entire supply chain inventory into account. Sterman’s research provides evidence that the participants have a tendency to underweight the existing inventory in the supply line. Schweitzer and Cachon (2000) also indentify irrational behaviour; individuals often exhibit some form of decision bias in business contexts. The study of Rong et al. found evidence “..that human behaviour creates an additional layer of variability to systems under supply disruptions...this introduces new challenges for designing and managing flexible supply chains.”

Lee et al. (1989) come to a different conclusion; the bullwhip effect is mainly caused by rational behaviour within the supply chain's infrastructure. Thus, if companies want to mitigate the bullwhip effect, they need to focus on modifying the infrastructure of the supply chain instead of changing the behaviour of decision makers. They identify four different causes of the bullwhip effect which all interact with the infrastructure of the supply chain:

1. Demand forecast updating

Every company in a supply chain forecasts for production and material requirements planning and inventory control. Forecasting is usually based on the historic order data from direct company customers. Simchi-Levi et al. (2008) state that if traditional inventory techniques based on period review policies and the single parameter base-
stock level are used in each individual stage of the supply chain, the estimates of the mean and the variability of customer demand are regularly modified. Upstream variability increases as a consequence. Lee et al. (1997A) emphasize the interpretation of data on occurring demand patterns data by supply chain management leading to adjustments in demand forecasts.

In this respect, Lee (2001) describes the story of the green Volvos. The Volvo marketing department decided to give a price discount on green cars because of excess inventory. This action created an artificial demand for green Volvos. The production department decided to ramp up production, creating an even greater inventory problem.

2. Order batching (the Burbridge effect)

When demand depletes inventories, companies usually do not start placing orders at an upstream organization immediately. Purchase orders are often batched; in fact they represent accumulated demand. This behaviour is caused by running the material requirements planning (MRP) not on a constant, but on a cyclical basis. Another cause is the trade-off between incurring ordering and storage costs, also known as the economic lot size model (Harris, 1915). Factors like economics of transportation, minimum order size requirements and the costs of handling and payment influence ordering costs. When ordering costs increase, customers have an incentive to postpone purchase orders. As a consequence, demand will become more irregular. If a company uses period ordering, naturally its upstream demand surges, followed by a period without orders; this amplifies variability and contributes to the bullwhip effect. Theoretically, if all customers showed this behaviour randomly, no significant bullwhip effect would occur. In the words of Cachon (1999); “The supplier’s demand variance is maximized when the retailers’ orders are synchronized (all retailers order in the same periods). It is minimized when the retailers’ orders are balanced (the same number of retailers order each period).” Lee et al. (1997A) state the latter rarely occurs; usually the surge in demand is even more
pronounced as customers tend to order at the same time. Such peaks are known as ‘MRP-jitters’. De Souza et al. (2000) only observed a minor influence of order batching as an individual factor.

3. Price fluctuation

According to Lee et al. (1997A), significant volumes in b2c and b2b markets are traded because of forward buying. Forward buying is a result of price fluctuations occurring in the market. These fluctuations can be due to special promotions (price discounts, payment terms, price terms, coupons, quantity discounts, rebates etc.). However, in the steel supply chain we already found evidence that price fluctuations result from dynamics in global commodity markets and global economic developments. The result is identical. Customers buy in quantities that do not reflect their actual and immediate demand; they buy in larger quantities to stock up, expecting extra profits.

4. Rationing and shortage gaming (the Houlihan effect)

In situations when a product’s supply capacity cannot meet its demand, manufacturers often ration their supply to customers. These customers anticipate by exaggerating their real needs when ordering. In a later stage, orders will cease and cancellations follow. Lee et al. (1997A) argue this behaviour is not an overreaction, but based on rational economic decisions and game theory in times of expected rationing. Shortage gaming thus occurs when customers’ orders do not represent real demand. Customers place identical orders at suppliers and buy at the first opportunity that occurs. This practice is common and mostly witnessed in the early life cycle stages of a product. Simchi-Levi et al. (2008) describe this cause as ‘inflated orders’. De Souza et al. (2000) identify this as the dominant cause for the bullwhip effect. Rationing was apparent in the steel industry in 2004 and to a lesser extent in 2007. It was caused both by excessive demands throughout the supply chain and by the production cuts mentioned in section 2.3.4.
A fifth cause of the bullwhip effect, lead time, is identified by Simchi-Levi et al. (2008) and other studies (Cachon, 2007; Alony and Munoz, 2007; Paik and Bagchi, 2006).

5. Lead time

Required safety and base stock levels are calculated by multiplying the estimates of the average and standard deviation of customer demand by the sum of the lead times and order review periods. Therefore the extrapolation from small fluctuations is magnified under conditions of long lead times. Long lead times also reduce the opportunities for correcting unfavourable patterns. Towill (1991) and Paik and Bagchi (2007) both divide this cause into lead times for information and for material. In the supply chain, transmission of material and information is typically subject to delays.

6. Other factors

De Souza et al. (2000) identify seven possible causes of the bullwhip effect by classifying two other factors; capacity constraints and poor coordination. Li et al. (2005) deduce from the existing literature three more abstractly stated, interrelated phenomena as causes of the bullwhip effect; bias demand information from the downstream chain members, delayed information transferring and unsuitable logistical operations responding to downstream demand. The most comprehensive set of causes is set by Paik and Bagchi (2007) who have identified 9 causes which they divide into 5 categories: (a) Supply chain structures and processes: (1) demand update forecasting, (2) order batching, (3) Rationing and shortage gaming, (4) price variations - (b) Material and information lead times - (c) Supply variability: (5) Machine breakdowns - (d) Other causes: (6) Capacity limits, (7) Number of echelons - (E) Additional causes: (8) Lead time variability, (9) Workloads.

Machine breakdowns are identified by Forrester (1958) and Taylor (1999) as the only real cause for supply variability. Chatfield et al. (2004) found no evidence of lead times initiating the bullwhip effect but found a correlation between the two variables. Akkermans and Vos (2003) found evidence of higher workloads that causing a higher
level of quality deficiencies. As a result, the necessary rework further increased workloads.

3.7 The bullwhip effect in the steel supply chain

Although the bullwhip effect originates from research on consumers products, it is widely applied in the context of industrial and commodity product markets (Cachon, 2007; Terland & Mankowitz, 2008; Glatzel et al., 2009). Suthikarnnarunai et al. (2009) conclude that in times when prices rises are expected, steel manufacturers and processors will increase their purchase volumes above the level of their expected demand. Consequently, in times of expected price falls, existing inventory is used to minimize purchasing extra material.

According to Simchi et al. (2008), achieving a sufficient level of communication and coordination in the supply chain should be an important objective for any company. Central coordination can reduce the effects of variability by improving forecasts and reducing lead times. However information in the supply chain is highly decentralized. Traditionally trust is not abundant in the steel sector. This is due to the ‘conservative’ nature of the business and to the standardization of the product (it is relatively easy to switch between suppliers). The presence of both integrated and independent steel distributors in the same market cause suppliers to be the same companies as competitors. The general level of distrust in the steel sector is attributable to the asymmetry of information (Lewicki and Buncker, 1995).

McCafferty states in Forward Online (issue September/October 2006): “The downturn that ravaged the steel industry between 2000 and 2003 created massive bullwhips.” He claims large steel consumers did not have sufficient incentives to push for efficiency in the supply chain and blames the fragmentation of the industry as a cause that keeps margins depressed. According to the Wall Street Journal (April 5, 2010) companies along the metals supply chain cut production and lived off existing inventories in expectation of a global economic collapse. Both restocking and destocking have the same instantaneous and powerful effect on demand and therefore were significant causes for the bullwhip effect. In 2004, Jim Owens, CEO of Caterpillar, the world’s largest manufacturer of construction and mining machines, said: “The inventory burn-
off is over”. His statement was part of a deliberate attempt by the company to boost production in the steel industry due to an expected rise in demand caused by restocking. As Caterpillar had experienced problems in times of strong growth, it deliberately contributed to the creation of the bullwhip effect. In his Industry News article (September, 2009), Katz also identified destocking at the end of 2008; manufacturers have cut or halted production while unloading inventory stockpiles that built up because of decreasing demand.

3.8 The bullwhip effect and the economic and financial crisis
Fransoo et al. (2010) find evidence that directly after the fall of Lehman Brothers on September 15, 2008, a shock wave hit the international business community instantaneously. Their study concludes that inventory depletion along the supply chain directly after the credit crisis was largely due to destocking; during the 2008/2009 financial crisis, the decrease in sales volume at companies up the supply chain was significantly higher compare to downstream echelons and the sales decline of companies further upstream in the supply chain was increasingly due to inventory reductions along the supply chain.

3.9 Managing the consequences of the bullwhip effect
Geary et al. (2006) identify two types of principles that can reduce the bullwhip effect. The first type are the actual causes of the bullwhip effect; inflated orders, lead times, price fluctuations, demand forecasting and batch ordering. The second type of principles is related to the design of the supply chain; control systems, time compression, centralization of demand information, eliminating echelons and synchronizing.

Simchi-Levi et al. (2008) have four suggestions for reducing the bullwhip effect. Reducing uncertainty by centralizing demand information, by providing complete and identical information simultaneously to each member of the supply chain. Magnification of demand variability due to individual forecasting and analysis could thus be eliminated. Second, reducing variability by trying to eliminate causes such as changes in price (promotions). Third, lead-time reduction of orders and information. If demand can be signalled earlier, the supply chain can react quicker. If delivery times
shorten, stocks can faster be replenished. The use of ERP/EDI systems could be a method to reduce lead times. Finally, strategic partnerships enhance information exchange and risk sharing.

In this research, findings are combined into 5 main solutions to reduce demand variability;

- Smoothing the flow of products; reduction of batch sizes, frequent (JIT) deliveries
- Information sharing; centralizing demand information
- Vendor managed inventory (VMI)
- Strategic partnerships
- Eliminate inherent variability; reducing price fluctuations and inflated orders

3.10 Quantifying the bullwhip effect

In addition to their statement on the difficulties in studying the causes of the bullwhip, Alony and Munoz (2007) concluded quantifying the degree to which each individual factor contributes to the bullwhip effect is even more difficult. DeSouza et al. (2000) benchmarked individual causes by using the beer game mode. By running a series of tests in which one variable is alternating set at zero they could analyze the influence of each factor.

Cachon (2007) does not focus on individual causes, but measures variability of purchase vs. sales orders; the volatility of demand imposed to that industry by its downstream customer vs. the volatility of the inflow on that industry, a measure we call production. The same method is applied

by Simchi-Levi et al. (2008) who calculate the bullwhip effect by comparing the variance of placed orders (Q) to the variance of customer demand (D).
4. DEMAND VARIABILITY IN THE DUTCH STEEL SECTOR

The first part of research is based on secondary data. This data is extracted from the ERP (SAP) and demand forecasting program (SLIM4) of a steel distributor and from the Dutch statistics agency CBS. These are monthly data collected from 2002 until the first quarter of 2011. Data from SLIM4 has been collected since 2004, when the program became operational. To exclude the influence of holidays, sales volumes are measured per official working day. In order to compare company data with market indicators, the researcher made use of the production index of industrial buildings (factories, warehouses, stables, etc.) in the Netherlands and the production index of the Dutch metal fabrication sector from CBS (www.cbs.nl). It is important to acknowledge these calculations exclude certain factors (lead times, commercial targets, competition). However, they are measured over a period of 6-8 years which dilutes these influences.

4.1 The extent to which demand variability is apparent in the Dutch steel sector

The extent of increase in demand variability when travelling upstream in the supply chain, can be quantified by comparing upstream and downstream variability (Simchi-Levi et al., 2008). From this, Cachon et al. (2007) conclude the difference in variability can be calculated by comparing purchase and sales orders levels at each member of the supply chain. On the distributor level, monthly purchase and sales volumes have been collected. Sales volumes of distributors equal purchase levels of steel processors. Downstream variability of steel processors (SCCs and SSPCs) is measured by means of secondary data from the production index of industrial buildings (factories, warehouses, stables, etc.) in the Netherlands and the production index of the Dutch metal fabrication sector from the Dutch statistics agency CBS (www.cbs.nl).

The researcher uses the coefficient of variance (CV%) to compare the level of variability. CV% is a normalized measure as this measure eliminates differences in means. The researcher determined relevant statistical values for each member of the supply chain from the data included in appendix 4A. The ‘Dutch industrial building volume index 2004-2010’ indicates SCCs experience a CV% in demand from their customers of 16.83. Upstream, distributors experience a CV% in demand from SCCs of 24.29. Thus we can conclude SCCs cause an increase of variance by 44.3%
Further upstream, steel mills experience a CV% in demand from distributors of 17.72, indicating distributors moderate variability by 27.0% (17.72/24.29). An identical calculation on the steel sheet supply chain shows an increase of demand variability between SSPCs and distributors of 84.4% (27.47/14.89). In their turn, distributors reduce upstream variability by variability 23.3% (21.05/27.47). Cachon et al. (2007) found a similar increase of 50% in the North American metal wholesale industry. This research also finds a dampening effect caused by steel distributors as they reduce variability in demand by 16.4% (sections) respectively 23.3% (sheets). Cachon et al. (2007) and Rong et al. (2006) acknowledge the existence of smoothing of variance, especially in the middle parts of the supply chain. They identify existing stocks as an important cause of this effect.

The same method was applied to establish demand variability between periods. The average demand variability experienced by distributors over 3 periods of time is shown in tables 4.4 and 4.5. CV% of demand (sections) at the distributor level shows an increase of 4.7% between 2002/04 and 2005/07 and of 62.7% between 2005/07 and 2008/10. Similar outcomes apply for sheet demand; demand variability increased by 7.1%, respectively 43.7%.

The researcher concludes that steel distributors have played an important role in moderating demand variability in the supply chain in recent years. The second conclusion is that demand variability moderately increased between 2002/06 and sharply increased between 2006/10.

4.2 The effect of demand variability on steel distributor performance
A higher demand variability results in higher forecast errors (Simchi-Levi et al., 2008). The researcher compared three categories of data on steel sections extracted from January 2004 to February 2010 (demand forecast errors, deviation of demand and stock service level). Data are included as appendix 4C. Statistical analysis reveals a significant moderate positive correlation between the monthly deviation of average sales volumes and monthly forecasting errors (r= .491, p< .001). Secondly, the researcher established if a correlation exists between the level of demand forecasting errors and the level of stock service levels, defined by the demand forecasting
program (SLIM4) as ‘the percentage of orders which can be satisfied from on-hand stocks’. Statistical analysis reveals a significant weak to moderate negative correlation between monthly forecasting errors and stock service levels ($r= -.311$, $p= .007$).

The researcher concludes that a higher variability in demand increases the level of forecasting errors, which in turn reduces stock service levels. This conclusion is confirmed by the graphical representation of data in figure 3. The findings confirm the negative impact of an increase of demand variability on stock service levels. Stock service levels were often too low (resulting in lower performance levels and increased costs due to extra expenditures for additional on-the-spot purchases) or too high (resulting in increased risks and capital requirements for keeping stock). Simchi et al. (2008) describe this as the trade-off between customer service and costs.

The capital requirement for keeping stock is represented by estimating the monthly value of the stocks between June 2004 and March 2011. This figure is calculated by multiplying the stock volume by the replacement value. It shows large fluctuations, resulting in a variation of capital requirements of 304% for sheets and 368% for sections.

![Relation between demand forecast and stock service level](image)

**Figure 3**: The relation between demand forecast errors and stock service levels

(source: author)
To investigate the effect on operational margins, the researcher compared data on demand (sales volume per working day) and net margin per ton in a graph. In this graph, the researcher indicates 9 points that visually indicate a negative correlation between margins and sales levels. Statistical analysis only reveals a negative weak insignificant correlation ($r = .073$, Sig. 451).

4.3 The level and the influence of demand variability on Dutch steel processors

The existing level of demand variability is measured by survey question 3 (CONS1); *The fluctuation of purchased volumes of steel by my company can be ranked as ...* This fluctuation can not be measured by analysis of company data because steel processors usually have more than one supplier. The influence of demand variability on customer performance is measured by survey questions 4, 5 and 6. CONS2 (*The impact of demand variability on my company’s performance is negative*) measures the positive or negative impact of variability on steel processors. CONS3 (*The impact of demand variability on my company’s present stocks is negative*) and CONS4 (*The impact of demand variability on my company’s running customer orders/projects is negative*) focus on two different aspects of this impact: on present stocks and on running orders/projects.

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<th>SSPCs</th>
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<td>3.98 .77</td>
<td>0.70 .110*</td>
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<td>CONS3</td>
<td>3.58 1.2 5</td>
<td>2.81 1.12</td>
<td>4.30 .88</td>
<td>-1.49 .000*</td>
<td>Reject</td>
</tr>
<tr>
<td>CONS4</td>
<td>4.72 1.0 5</td>
<td>4.97 1.25</td>
<td>4.50 .75</td>
<td>0.47 .580*</td>
<td>Retain</td>
</tr>
</tbody>
</table>

* Kolgomorov-Smirnov test for ranked data, significance level .05

Table 4: Descriptive analysis of consequences of demand variability including significance testing between categories

SCC and SSCP (source: author)
SSPCs generally experience a higher level of variability in volumes of steel purchased, but are less exposed to negative consequences. The financial consequences that both categories experience are in line with the nature of their respective ordering patterns; process/stock vs. project/order orientated. SSPCs experience a negative impact on their existing stocks. Because SCCs mainly purchase directly for customer orders, they have a lower score. In return, SSPCs experience a lower negative impact on running orders/projects. The Kolgomorov-Smirnov test for ranked data reveals that both the level of demand variability (CONS1) and the difference of financial risk on holding stock (CONS3) are statistically significant (p= .000).

### 4.4 The influence the bullwhip effect on Dutch steel processors

<table>
<thead>
<tr>
<th>Independent variables (the bullwhip effect)</th>
<th>All cases</th>
<th>SCC</th>
<th>SSPC</th>
<th>SCC-SSPC</th>
<th>Hypothesis testing: SCC=SSPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor Inflated Orders (IO)</td>
<td>5.12</td>
<td>4.95</td>
<td>5.28</td>
<td>-0.33</td>
<td>Sig. .825* Retain</td>
</tr>
<tr>
<td>Factor Lead Times (LT)</td>
<td>4.34</td>
<td>4.54</td>
<td>4.15</td>
<td>0.39</td>
<td>Sig. .447* Retain</td>
</tr>
<tr>
<td>Factor Price Fluctuations (PF)</td>
<td>4.72</td>
<td>3.66</td>
<td>5.85</td>
<td>-2.19</td>
<td>Sig. .000* Reject</td>
</tr>
<tr>
<td>Factor Batch Ordering (BO)</td>
<td>5.22</td>
<td>4.76</td>
<td>5.65</td>
<td>-0.89</td>
<td>Sig. .004* Reject</td>
</tr>
<tr>
<td>Factor Demand Forecasting (DF)</td>
<td>4.77</td>
<td>4.38</td>
<td>5.13</td>
<td>-0.75</td>
<td>Sig. .002* Reject</td>
</tr>
</tbody>
</table>

* Kolgomorov-Smirnov test for ranked data, significance level .05

Table 5: Descriptive analysis of the independent variables related to the bullwhip effect and significance testing between categories SCC and SSPC (source: author)

From the variables contributing to the bullwhip effect inflated orders and batch ordering received the highest attribution by respondents. Between both categories, SSPCs scored highest on price fluctuations and demand forecasting. Ordering steel for stock replenishment makes SSPCs focus much more on demand forecasting and stock control. In addition they attribute a significantly higher value to sharing demand information in the supply chain compared to SCCs. SCCs responded high on lead times.
and on inflated ordering as a possible method to cope with availability, but low in an active pursuit of this strategy and on price fluctuations. However, although customers of SCCs don’t adapt their actual demand to price expectations, their price negotiation strategy largely depends on it. As a result, SCCs and distributors face a higher demand variability and increased risks. When price fluctuations occur, SSPCs can more easily adapt their purchase volumes to the market situation. This is confirmed in the results on item CONS1, which indicates a higher degree of demand variability caused by SSPCs. Cachon et al. (2007) identified a similar significant association between price differences and demand variability.

Order batching is less apparent in the SCC sector. Their purchase orders mainly consist of individually specified, cut-to-length sections for uniquely designed building projects. Order batching typically leads to a delay in information and demand shock, as purchase orders are bundled (Alony, I., and Munoz, A., 2007). Steel sheets are typically delivered per mill packet of 2,500-5,000 kilograms to ensure an attractive purchase price. SSPCs confirm material price as the most important cause for batch ordering. The factors price fluctuations and batch ordering show a strong positive correlation to the level of demand variability.

Overall, analysis reveals the bullwhip effect to be the strongest predictor of demand variability as the independent variable price fluctuations (PF) is the most important determinant for demand variability. The second determinant is batch ordering (BO).

### 4.5 The influence of production smoothing on Dutch steel processors

For SSPCs production smoothing is an important method to dampen the effects of demand fluctuations from downstream customers. A prerequisite for production smoothing is knowing future demand will come. The existence of long-term contracts is such a condition, of which the existence is confirmed by survey question 9 (PS3). Cachon et al. (2007) identify the importance of a low variability in order levels from downstream customers. This aspect is confirmed by the moderate response on survey question 15 (PT1) on the level of disruption of customer demand.

The literature review shows mixed opinions on the effectiveness of production smoothing. Blanchard (1983) concludes ‘...inventory behaviour is destabilizing; the
variance of production is larger than the variance of sales’. In this survey respondents indicate production smoothing does not lead to a lower level of demand variability; it has a strong positive relationship to the variability in purchase volumes ($r_S = .603$, $p<.001$). This finding is in contradiction to the literature review which revealed production smoothing as a cause for lower levels of demand variability. The researcher concludes SSPCs enjoy a certain degree of freedom in timing their purchase orders: SSPCs generally experience a lower level of customer involvement in their production planning (PT3). Purchasing steel in a favourable market can lead to important cost advantages. This is confirmed by the low score on CONS2; demand variability does not heavily affect SSPCs performance. It is also confirmed by the role price fluctuations have in determining purchasing policies; SSPCs are much more focused on future market developments (factor PF). Binder (1986) confirms production smoothing is often much more related to price fluctuations than it is related to demand fluctuations.

Finally SSPCs have greater opportunities to use material for other purposes, making them more flexible than SCCs. SCCs mainly produce for unique building projects. They are dependent on the planning of the entire project, in which the steel construction is only a part. Often last minute changes occur. Therefore engaging in production smoothing is usually not an option. This is confirmed by the low score of SCCs in this survey.

When regarded as a single factor, production smoothing has an overall significant correlation to the level of demand variability and is an important contributor as such. This is confirmed by Cachon et al. (2007) who define the metalworking industry as a ‘production smoother’. However, in combination with the bullwhip effect and price elasticity, no significant cause-and-effect relation could be determined.

<table>
<thead>
<tr>
<th>Independent variables (production smoothing)</th>
<th>All cases</th>
<th>SCC</th>
<th>SSPC</th>
<th>SCC-SSPC</th>
<th>Hypothesis testing: SCC=SSPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Factor Prod. Smoothing (PS)</td>
<td>4.10</td>
<td>1.37</td>
<td>2.97</td>
<td>.98</td>
<td>5.15</td>
</tr>
</tbody>
</table>

* Kolgomorov-Smirnov test for ranked data, significance level .05
Table 6: Descriptive analysis of independent variable related to production smoothing and significance testing between categories SCC and SSPC (source: author)

4.6 The influence of price elasticity of demand on Dutch steel processors

Overall, respondents attributed a moderate value to their exposure to factors that increase price elasticity of demand. SCCs are more exposed to peak times. In the previous section it was concluded that they often don’t engage in production smoothing and are more dependent on short and reliable lead times (LT). Despite moderate values, the researcher found correlations between two factors causing price elasticity level of demand and demand variability. First, the factor alternative uses (AU) has a moderate to strong positive correlation. This relates to our findings on minor research question 3; when existing stocks have alternative uses, the customer becomes less dependent on single articles and enjoys a greater freedom in timing purchase orders. Accordingly, a high score on the factor AU reduces the impact on running orders/projects. However it also leads to a higher impact on existing stocks, which is explained by the existence of much higher stock levels among this category of steel processors.

Budget ratio is identified as being a positively correlated to price elasticity of demand (Lamb *et al.*, 2010). This is not confirmed by this research; budget ratio (BR) has a significant correlation to all aspects of demand variability. Companies which can add more value to their purchased steel experience a more positive impact of demand variability on their performance, hence they are less influenced by steel market dynamics. They also enjoy a greater freedom in timing, which results in a larger variability. Finally, they experience a smaller impact of demand variability on their existing stocks. Overall the researcher concludes the demand of SCCs is more inelastic due to a lack of available substitutes, durability (SCCs cannot delay production) and a lack of alternative uses. Despite a higher budget ratio, SCCs have only limited options to determine the moments at which they purchase steel from distributors.

When applying multiple linear stepwise regression, price elasticity of demand is not a significant cause of demand variability. However, a cause-and-effect relationship exists
between budget ratio and the impact of demand variability on company performance, explaining 19.2% of variation. Steel processors that can add the most value to their purchased products are a less negatively impacted by variability in demand. The level of alternative uses is a moderate predictor for the impact of demand variability on existing stocks.

### Table 6: Descriptive analysis of independent variables related to price elasticity of demand and significance testing between categories SCC and SSPC (source: author)

<table>
<thead>
<tr>
<th>Independent variables (price elasticity of demand)</th>
<th>All cases</th>
<th>SCC</th>
<th>SSPC</th>
<th>SCC-SSPC</th>
<th>Hypothesis testing: SCC=SSPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor Peak Times (PT)</td>
<td>Mean 4.31</td>
<td>.67</td>
<td>4.54</td>
<td>.69</td>
<td>.44</td>
</tr>
<tr>
<td>Factor Alt. Uses (AU)</td>
<td>Mean 4.14</td>
<td>1.62</td>
<td>2.89</td>
<td>1.32</td>
<td>-2.41</td>
</tr>
<tr>
<td>Factor Budget Relation (BR)</td>
<td>Mean 37.0%</td>
<td>15.6</td>
<td>48.1</td>
<td>12.21</td>
<td>21.29</td>
</tr>
</tbody>
</table>

* Independent groups T-test for numerical data, significance level .001
** Kolgomorov-Smirnov test for ranked data, significance level .05

#### 4.7 Conclusions on the causes of demand variability for Dutch steel processors

For this purpose, the researcher used the non parametric Spearman’s rank correlation coefficient (Spearman's rho) test. To assess cause-and-effect relationships, the researcher applied multiple linear (stepwise) regression on significantly correlating variables. This method shows the combined influence of significant independent variables, therefore improving the value of the prediction. The r-values of multiple regression are higher then each individual coefficient, indicating that a larger part of variance is explained. As a result, the number of significant determinants decreases. All coefficients are shown in table 7.
## Correlations between dependent variables (CONS 1-2) versus independent variables and general characteristics

<table>
<thead>
<tr>
<th>All factors Spearman’s Rho (Pearson’s PMCC)</th>
<th>(N=77), factor BR</th>
<th>CONS1</th>
<th>CONS2</th>
<th>CONS3</th>
<th>CONS4</th>
</tr>
</thead>
<tbody>
<tr>
<td>The bullwhip effect</td>
<td>Factor IO</td>
<td>Correlation Coeff.</td>
<td>0.252*</td>
<td>0.113</td>
<td>0.122</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.027</td>
<td>0.329</td>
<td>0.289</td>
</tr>
<tr>
<td></td>
<td>Factor LT</td>
<td>Correlation Coeff.</td>
<td>-0.044</td>
<td>0.134</td>
<td>-0.246*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.706</td>
<td>0.246</td>
<td>0.031</td>
</tr>
<tr>
<td></td>
<td>Factor PF</td>
<td>Correlation Coeff.</td>
<td>0.758**</td>
<td>-0.323**</td>
<td>0.704**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.000</td>
<td>0.004</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Factor DF</td>
<td>Correlation Coeff.</td>
<td>0.318**</td>
<td>-0.036</td>
<td>0.329**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.005</td>
<td>0.753</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>Factor BO</td>
<td>Correlation Coeff.</td>
<td>0.530**</td>
<td>0.003</td>
<td>0.256*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.000</td>
<td>0.977</td>
<td>0.025</td>
</tr>
<tr>
<td>Production smoothing</td>
<td>Factor PS</td>
<td>Correlation Coeff.</td>
<td>-0.069</td>
<td>0.066</td>
<td>-0.136</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.551</td>
<td>0.568</td>
<td>0.240</td>
</tr>
<tr>
<td>Price elasticity of demand</td>
<td>Factor PT</td>
<td>Correlation Coeff.</td>
<td>0.517**</td>
<td>-0.268*</td>
<td>0.655*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.000</td>
<td>0.019</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Factor AU</td>
<td>Correlation Coeff.</td>
<td>-0.384**</td>
<td>0.362**</td>
<td>-0.454**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.001</td>
<td>0.001</td>
<td>0.000</td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

### Table 7: Correlation coefficients: independent variables and demand variability
*(source: author)*

Regression analysis shows that in combination with other variables, price fluctuations (PF) is the strongest predictor of demand variability for CONS1, causing 58.4% (p< .001) of variance. If the factor PF increases by .100, it will increase demand variability by .669. Batch ordering (BO) ranks second; both variables cause 61.7% of variability (p= .014). An increase of BO by .100 will increase demand variability by .204. The other
variables (DF, AU, PS and BR) are only significant on an individual level. For CONS2, the
only predictor is budget ratio (BR), accounting for 19.2% (p< .001) of variability. CONS3
is predicted by price fluctuations (PF/48.0%, p< .001) and by alternative uses (AU/4.7%,
p= .008). Finally, CONS4 is again determined by price fluctuations (PF/11.6%, p= .002).

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Theory</th>
<th>Independent variable</th>
<th>Linear regression method</th>
<th>Correlation coefficient</th>
<th>R square</th>
<th>Sig.</th>
<th>ANOVA Sig.</th>
<th>Beta Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONS1</td>
<td>BWE</td>
<td>Factor PF</td>
<td>Multiple</td>
<td>.758**</td>
<td>.584</td>
<td>.000</td>
<td>.000</td>
<td>.669</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Factor BO</td>
<td></td>
<td>.530**</td>
<td>.033</td>
<td>.014</td>
<td>.000</td>
<td>.204</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Factor DF</td>
<td></td>
<td>.318**</td>
<td>-</td>
<td>.418</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PS</td>
<td>Factor PS</td>
<td></td>
<td>.603**</td>
<td>-</td>
<td>.981</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PEOD</td>
<td>Factor AU</td>
<td></td>
<td>.517**</td>
<td>-</td>
<td>.337</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Factor BR</td>
<td></td>
<td>-.384**</td>
<td>-</td>
<td>.357</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CONS2</td>
<td>BWE</td>
<td>Factor PF</td>
<td>Multiple</td>
<td>-.323**</td>
<td>-</td>
<td>.308</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PS</td>
<td>Factor PS</td>
<td></td>
<td>-.385**</td>
<td>-</td>
<td>.057</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PEOD</td>
<td>Factor AU</td>
<td></td>
<td>-.268*</td>
<td>-</td>
<td>.632</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Factor BR</td>
<td></td>
<td>.362**</td>
<td>.192</td>
<td>.000</td>
<td>.000</td>
<td>.438</td>
</tr>
<tr>
<td>CONS3</td>
<td>BWE</td>
<td>Factor LF</td>
<td>Multiple</td>
<td>.246*</td>
<td>-</td>
<td>.180</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Factor PF</td>
<td></td>
<td></td>
<td>.704**</td>
<td>.480</td>
<td>.000</td>
<td>.000</td>
<td>.693</td>
</tr>
<tr>
<td></td>
<td>Factor DF</td>
<td></td>
<td></td>
<td>.329**</td>
<td>-</td>
<td>.995</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Factor BO</td>
<td></td>
<td></td>
<td>.256*</td>
<td>-</td>
<td>.242</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PS</td>
<td>Factor PS</td>
<td></td>
<td>.668**</td>
<td>-</td>
<td>.097</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PEOD</td>
<td>Factor AU</td>
<td></td>
<td>.655**</td>
<td>.047</td>
<td>.008</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Factor BR</td>
<td></td>
<td>-.454**</td>
<td>-</td>
<td>.208</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CONS4</td>
<td>BWE</td>
<td>Factor PF</td>
<td>Multiple</td>
<td>-.299**</td>
<td>.116</td>
<td>.002</td>
<td>.002</td>
<td>-.341</td>
</tr>
<tr>
<td></td>
<td>PEOD</td>
<td>Factor AU</td>
<td></td>
<td>-.305**</td>
<td>-</td>
<td>.383</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

Table 8: Multiple linear regression analysis between significantly correlated
independent variables

and survey questions on demand variability (source: author)
4.8 Comparing process and project orientated steel processors

Many different values and patterns occur between respondents that buy sections (SCCs) and sheets (SSPCs). Overall SCCs cause a lesser degree of demand variability to distributors, although they are exposed to a higher degree of demand variability from their customers. This results in a higher level of peak times in their production. In the SCC market, the majority of demand comes in the form of building projects, consisting of a unique combination of materials (AU). Often SCCs depend on definitive drawings, as many changes occur. Small changes can result in drastic changes in input material because of lengths and strength of profiles. This makes it difficult for SCC to standardize production and use material from stock. Unpredictable demand also allows a low degree of production smoothing because producing early imposes a risk. As a consequence, SCCs often perform last-minute just-in-time purchases. Thus, their demand is a reflection of their real-time material requirements. Length and reliability of lead times becomes more important. Batch ordering and inflating orders are less prevalent. Even though SCCs indicate material availability and lead times as more important than SSPCs, they engage significantly less in inflating orders in times of shortages. Demand forecasting is less important; SCCs generally deal with immediate demand. The period between the fixing of project prices and the moment of steel purchases varies. SCCs are less involved in showing actively causing the bullwhip effect and production smoothing but are more exposed to negative consequences of these phenomena in terms of risk, performance and dependency.

SSPCs have a wider array of measures when coping with the demand variability of downstream customers as they hold stock. As a consequence, these inventories are a source of risk for SSPCs. Inventories are indicated to have a smoothening effect on demand variability by Cachon et al. (2007), Rong et al. (2005) and Boute et al. (2007). According to Buffa and Miller (1979), ‘inventory acts as a buffer, absorbing increases or decreases in demand while production remains relatively steady’. However, many business articles conclude the opposite in the steel supply chain (Aeppel, 2010, Laing, 2010, McAfferty, 2006); inventories are used up in times of expected price decreases and built up in times of expected increases. Therefore inventories can increase demand variability as well as dampen it.
4.9 Conclusions

These outcomes lead to the following main conclusions in respect of the factors that cause demand variability in the Dutch supply chains of steel sections and sheets:

1. The bullwhip effect is the most important cause for demand variability in the Dutch supply chain of sections and sheets. Multiple (stepwise) regression analysis indicates that of the independent variables that cause the bullwhip effect, price fluctuations (PF) is the most significant predictor. Batch ordering (BO) ranks second.

2. SSPCs generally initiate more actions that lead to the bullwhip effect. Lead times (length and reliability) is the only aspect which is rated higher by SCCs.

3. Production smoothing mainly exists in the SSPC sector because of long term contracts. Production smoothing (PS) has a strong positive correlation to demand variability. Also, the ability to hold inventories causes an increased demand variability of steel sheets for distributors.

4. Two independent variables linked to price elasticity of demand have a significant correlation to demand variability. Alternative uses (AU) is strongly positively correlated and budget ratio (BR) is strongly negatively correlated. Overall, price elasticity of demand is not identified as a significant predictor for the level of demand variability.

5. IDENTIFYING POSSIBLE SOLUTIONS

The results from the survey clearly indicate price fluctuations as the major cause of demand variability with its unfavourable side effects. So, how can these effects be mitigated, especially since the causes of the fluctuations have been identified as lying in on a global steel level. To address this problem, 14 in-depth unstructured interviews have been conducted with medium/large Dutch steep processors.
5.1 Possible solutions for the SCC sector

SCCs manufacture steel constructions by using traditional techniques such as drilling, welding and bending. Most SCCs outsource surface treatment. Assembling, a core activity of SCCs, is performed in-house. Three types of construction projects are identified. Each type is different in relation to the issuers, the role of the SCC, the risks involved, competition between SCCs and the possibilities to create added value. These differences put specific demands on the relationship between SCCs and steel distributors, leading to different counter measures. A positive correlation exists between the size of the SCC and the size of the construction project the company engages in.

Reducing uncertainty/centralizing demand information

Overall, centralizing demand information is not a key focus for the project orientated SCCs. In particular SCCs focusing on medium/smaller regard demand as being unpredictable and unfit to forecast or share. Each project consists of a unique specification for sections in type (size and strength), length and sometimes quality. These specifications often change due to cost reductions, technical improvements and changing requirements set by end users. The majority of SCCs tender after the development phase. Purchasing is often executed on a last-minute basis due to delays in the approval of specifications. This leads to time pressure in the execution of construction projects. In the words of Shenhar and Laufer (1995); today’s construction projects are ‘complex, uncertain and quick’. This is confirmed by the survey score for DF3 (a low overview of customer demand/score 3.68) and DF4 (a low level of sharing demand information/score 3.92), as stated in appendix 4F.

SCCs rely on distributors to (just-in-time) supply a wide range of sections from stock which are cut to specification. Regular qualities and lengths are readily available. Each supply chain member tries to reduce costs by engaging in sub-optimization. Strong competition between distributors leads to small price differences. Distributors are faced with high stock safety levels and waste percentages to meet the requirements of the construction sector. The incentives for smaller SCCs to engage in close relationships with steel distributors are low. Large SCCs, targeting large projects are often involved in
the design phase of projects. Steel sections used in these projects are often pre-ordered via distributors from rollings at steel mills. SCCs can create cost advantages by the optimal use of existing stock programmes, price lists and by optimizing the logistical processes. Steel distributors play an important role in financing by offering SCCs credit facilities. As a result, the necessary coordination leads to an increased level of information sharing in the supply chain.

**Smoothing the flow of products**

Overall, interviewees acknowledge the importance of just-in-time deliveries per individual, cut-to-length sections by steel distributors. SCCs involved in medium/smaller projects rely heavily on the quality, speed and reliability of steel distributors. Availability is regarded a key issue. Lee et al. (1997A) acknowledge the importance of decreasing lead times as a contributor to a lower variability in demand.

SCCs indicate a that a higher degree of standardization of the section types used for constructions could reduce the risk of obsolete material due to specification changes, especially in medium/smaller projects. It could also facilitate distributors; reducing the number of slow movers creates reduced overlap, clearer demand information and improved stock service levels (McAfferty, 2006, Tommelein et al. 2008). Simchi-Levi et al. (2008) call this ‘the product variety/inventory trade-off’.

**Eliminating inherent variability; reducing price fluctuations and inflated orders**

All interviewees indicated price fluctuations to be a major cause for concern for the supply chain, confirming the findings of the survey. Decreasing price fluctuations is expected to contribute substantially to smoothen the flow of products though the supply chain. Demand for constructions is largely independent of the (expected) price level of steel. Despite the fact that for most contractors of industrial buildings (project developers, government institutions, investment firms) the cost of steel components only accounts for around 7 to 13% of the total investment (Evers et al. 2003). Contractors often fix prices or engage in re-negotiations if market developments favour them. SCCs try to mitigate risks by optimal timing; they purchase at the last minute.
when prices are expected to decrease and they enter into medium term contracts when prices are expected to rise. This behaviour increases the risks for the distribution sector. Furthermore, in today's volatile steel market, fixing purchase prices in combination with material reservations increases the risk of obsolete stocks.

The only interviewee that did not attribute value to this role is a turnkey builder for whom the average share of the cost of steel sections only accounts for 15-20% of its sales prices. In contradiction to smaller SCCs, the two largest interviewed SCCs actively anticipate on price fluctuations by purchasing large volumes of steel when prices are perceived as being low. These SCCs acknowledge the fact that their purchases can cause extra price volatility. In fact, for these firms, the bullwhip effect is an option to improve margins. A similar strategy has recently been pursued by Caterpillar (Wall Street Journal, January 27, 2010). When these SCCs make correct assumptions about the price development, they experience an advantage early after their purchases, as they can secure projects at low prices while maintaining reasonable margins. However they also identify important disadvantages. Stock holding causes extra administration and financing costs. When most sections are used, mostly slow movers remain, causing increased waste percentages. Also, these SCCs incur price risks, as future price developments are unknown. The existing stocks cause extra pressure on the margins of other SCCs, especially in times when steel prices rise.

**Vendor managed inventory (VMI)**

VMI is not considered a real option by most SCCs because they hold no significant stocks. The SCCs that do so to create medium term price advantages regard their inventories as a part of their individual strategy. No involvement of steel distributors is desired.

**Strategic alliances**

According to Tommelein et al. (2006) strategic alliances and supply chain management in a construction project environment can help to increase the influence of SCCs on the project definition, design, supply, assembly and use. Ballard et al. (2004) highlight the
increased options for work structuring resulting in improved supply chain performance and resource allocation. As a result, the supply chains become more competitive and customer orientated. In particular SCCs targeting project type 1 acknowledge these factors as being important. They are increasingly focusing on improving their relationship with steel distributors. Their main goal is to achieve a larger degree of price stability, secure availability and share project risks. SCCs identify trust as the prevailing condition to achieve this goal. The importance of trust is emphasized by Clark and Hammond (1997) who suggest that trust still has to emerge in many value stream relationships, the inhibition being the persistence with traditional “adversarial win-lose negotiations”. According to Li et al. (2007), maximum benefits can only be achieved when alliances have a long term character. Thus, both partners must be willing to sacrifice short term gains in order to create a more profitable long term alliance.

The formation of strategic alliances is hampered by several factors. First, a majority of SCCs indicate purchase management is a delegated part of project management. Each project manager is responsible for project revenues. The fragmentation of the purchase function leads to sub-optimization and hampers company policy development and execution. Second, due to cost savings the average quality of the purchasing function of SCCs has deteriorated in recent years. Third, the extensive range of sections (size, quality and length) and the importance of quick, just-in-time delivery cause SCCs not to rely on a single supplier. Fourth, SCCs find competition between steel distributors a necessary condition to achieve the lowest possible purchase price. This contradicts Li et al. (2007), who indicate that strategic alliances cause downstream customers to lose control over the relationship with suppliers. Fifth, by spreading credit facility risks SCCs create some degree of flexibility. Finally, the current oligopolistic market structure leads to intense price competition. Long term relationships with cost advantages for both parties are therefore difficult to create.

5.2 Possible solutions for the SSPC sector
The majority of the SSPCs interviewed acknowledge the irregular pattern of their steel purchases. In particular larger SSPCs that serve a wide array of customer segments by using standard quality sheets try to time their moments of purchase optimally. The
existence of inventories is an important condition for them to be able to do so. Buffa and Miller (1979) identify inventories act as a buffer, absorbing increases and decreases in demand. Blanchard (1983) concludes the opposite; ‘.inventory behaviour is destabilizing’. This is confirmed by Blinder and Mancini (1991) and by the findings of the survey questions about the role of the inventories of SSPCs.

The strategy of SSPCs has changed in recent years. Due to a lower level of local industrial activities and outsourcing to low cost countries, the total market volume has decreased. SSPCs are focused on adding value by increasing their flexibility and processing portfolio. They design and manufacture more complex products in smaller lot sizes. The share of the cost of steel has declined. Most SSPCs produce by using sheets from their own stock. Frequently, sheets are stored in cassette systems which are an integral part of the processing equipment. The use of advanced techniques and automated production is an important development in the sector. It requires a high quality standard of input material. Recently, the number of different steel qualities used for special applications has increased, offering distributors the option of improving their value proposition on the basis of their product range.

Reducing uncertainty/centralizing demand information

Being stockholders, SSPCs naturally engage more in analyzing demand and stock management than SCCs. Their survey score in respect of demand forecasting (DF) is 5.65 which is significantly higher than that of SCCs (appendix 4F). Interviewees indicated that the availability of material, especially for longer term contracts was their most important motivation to engage in sharing demand information with suppliers. SSPCs using special steel qualities rely much more on supplier relations. Standard steel qualities are commonly available and are purchased at spot markets.

Three trends are likely to cause an increase in the sharing of demand information. First, the majority of SSPCs are experiencing a higher demand for increased price stability from their customers. In this respect, SSPCs acknowledge the importance of a closer cooperation with steel distributors. Second, SSPCs are trying to increase their added value by improving flexibility and by introducing high tech processing techniques. Their
approach is changing from production oriented to integrated and solution based offerings. Using special steel qualities for niche products is an important aspect of this change. Third, the increased use of high tech production equipment facilitates information sharing. This equipment relies on the use of sophisticated hardware and software which is also suitable for managing stocks and sharing information. As a result, supply chain effectiveness is likely to increase in the future.

**Smoothing the flow of products**

The flow of sheets through the supply chain is more irregular compared to the flow of sections. Distributors offer significant price advantages for delivering sheets per mill package of 2-4 tons or full truckloads. Purchasing in mill packages also facilitates the process of identification and certification. SSPCs hold their own stocks and have a degree of freedom to time their purchases. In times of expected price drops, SSPCs can wait. One medium sized SSPC indicated the optimal lot size forces the company to order slow movers on average once every two months.

**Eliminating inherent variability; reducing price fluctuations and inflated orders**

The majority of the interviewees favour price stability. In recent years, customers of SSPCs accepted shorter term contracts. However, today SSPCs are experiencing an increased pressure to fix prices on a longer term. SSPCs indicate that if distributors can offer medium-term price fixing, it will have a positive effect on decreasing the variability in demand.

**Vendor managed inventory (VMI) and strategic alliances**

Most interviewees regard VMI to be an attractive option, in particular in combination with monthly billing and contracts that aim to secure availability. SSPCs who specialize in processing special steel qualities which are supplied by a single distributor often already engage in partnerships. Important aspects of these partnerships are a mutual interest in optimizing the material and processing quality, securing availability and
reducing price and stock risks. Another important aspect is the ability to secure supply of material in a constant quality. Forming a partnership with a supplier sets favourable conditions to achieve this goal. Larger SSPCs process standard quality sheets which are generally purchased at spot markets. The lot size of their orders secures low prices. The volume also requires large SSPCs to have more than one supplier and sometimes to purchase directly from steel service centres. VMI is not yet widespread. Consignment stocks, usually located at the distributor, do exist in the supply chain.

5.3 Conclusions
Overall, interviewees identified different problem areas for which distributors can offer different solutions to suit their individual needs. Steel processors acknowledge the improvements the distribution sector has made in recent years to supply just-in-time and made to specifications. Recent years are characterized by a high volatility in price and availability; distribution has been an essential part of the supply chain. The combination of fluctuations and a declining demand for steel products have lead to a difficult situation for steel processors. Until today, most processors are not inclined to look for solutions outside their sector. However, especially among SSPCs, this view is changing. The options for cooperation between echelons in the supply chain will increase in the near future.

Arbulu and Ballard (2004) find the construction industry is still in exploration toward a holistic vision on its supply chain. The industry is dominated by specialization within functions and great fragmentation (Tommelein et al. 2003). Interviewees confirm SCCs are still hampered by the design of the steel construction supply chain. Only large SCCs are often involved in the design phase of large and long term projects. The majority of SCCs are tendering after the development phase. This practice increases demand variability because it leads to a high level of uncertainty. Demand is still ‘an unpredictable sum of incidents caused by the character of the sector’, as one interviewee stated. Thus, the construction sector relies on distributors supplying a wide range of sections just-in-time and cut to length, eventually resulting in sub-optimization as each supply chain member tries to reduce costs. Simchi-Levi et al. (2007) identify the importance of delaying product differentiation as long as possible. This allows products to stay generic and thus be used for different purposes.
Distributors which cut to length comply with this principle. However due to unpredictable demand and short lead times they are still faced with higher stock safety levels and waste percentages. Tommelein et al. (2008) emphasize the importance of standardization for products used in the construction market as it reduces the workload pertaining to submittals and approvals, simplifies all handling and allows for risk pooling. According to Ballard and Howell (1994), standardization can only be achieved when applied in the design phase of a project. Distributors can have an important role in determining the level of standardization. However, standardization could have a negative impact on the opportunities for distributors to add value by offering unique product ranges and/or offering specialties.

Significant reduction of variability in demand will probably be difficult, especially as it requires a redesign of the construction supply chain. Notwithstanding this, distributors have the option to tighten relationships with SCCs on an individual basis. SCCs are increasingly searching for options to increase their added value by being involved in the design phase of projects. Price fluctuations are regarded as being undesirable. Engaging in strategic alliances to share risks could be a real option. In today’s volatile market, distributors must carefully assess the acceptable risk levels. In the current supply chain this means the number of strategic alliances should be restricted. The long term rewards of strategic alliances can create benefits: limitation of waste percentages, decreasing handling and transport costs and improving demand forecasting accuracy and a larger degree of price stability.

SSPCs have a larger influence on the pattern of their purchase. Not all SSPCs regard the influence of variability in demand and price as being negative. SSPCs which rely on special material qualities acknowledge the importance of a good relationship with suppliers. Overall SSPC are technically much better equipped to share information in the supply chain. Distributors have several options to smoothen demand variability as they can focus on sales contracts that fix prices on a medium term and design contracts that allow smaller lot sizes at favourable prices. Literature provides solutions to mitigate increases in costs as a result of batch ordering; consolidating loads from multiple suppliers located near each other (Paik and Bagchi, 2007) and the use of advanced information technology (Simchi-Levi et al. 2008).
Distributors and selected SSPCs can engage in strategic partnerships and create vendor managed inventory. However, because the price of steel is determined in the global market, fixing prices in the supply chain requires a high level of trust and willingness to engage in long-term relationships. Steel distributors can also reduce uncertainty without entering into strategic alliances. According to Özer and Wei (2006), alternative contract forms between suppliers and customers can focus on providing incentives to reveal buyer’s true forecasts and to match purchasing patterns to actual demand patterns. Capacity reservation contracts relate between establishing guaranteed availability and price setting. Advanced purchase contracts relate between demand uncertainty and price security. Paul and Bose (2004) identify price-only and buyback contracts to smoothen demand. The research shows that SSPCs are willing to engage in such contract forms.

5.4 Possible solutions for steel distributors
The literature review revealed that the price of steel is determined by global factors, independent of Dutch market dynamics. To reduce uncertainty caused by price fluctuations, members of the supply chain have to cooperate in order to decrease system wide risks. Despite the traditional ‘adversarial win-lose character’ of the sector, a number of SCCs consider strategic alliances an attractive option. However, a number of conditions do not favour the existence of strategic alliances: short term project cycles, competition between distributors as a necessary condition to achieve low prices, securing availability and the fragmentation of the purchase function. SCCs identify trust to be the most important requirement to form alliances. The interviews reveal that on an individual basis, this trust exists. Because of the capital intensive character of steel, distributors should carefully choose where they engage in alliances in order to limit the overall risks. Smaller SCCs targeting type 2 and 3 construction projects often buy sections on the spot market. They have no apparent incentives to cooperate with their suppliers. Larger SCCs targeting type 1 construction projects are already engaged in closer relationships with distributors. These relationships can be extended into the area of demand forecasting. Larger SCCs increasingly look for partnerships to decrease financial risks, secure material availability and share financial risks. Distributors can play an important role because of their insight into future market
conditions, their inventories and their financial strength. The researcher concludes distributors should opt to put greater focus on the creation of strategic alliances based on long term relationships and mutual benefits.

Overall SCCs indicate availability and just-in-time delivery to be important aspects of the service of steel distributors. SCCs targeting type 2 and 3 construction projects especially depend on these aspects. The design of the supply chain creates uncertainty and pressure on lead times. Smaller SCCs try to increase their added value and to reduce their dependence, but they have limited power in the supply chain. Achieving a higher level of standardization in sections would make SCCs less vulnerable to incidents occurring in the course of their projects. It would result in smoother demand patterns. Standardization would also reduce the number of slow movers, improve demand information and increase service levels for distributors. Because of their role in the supply chain, distributors can have an important role in determining the level of standardization. This would, however, have a negative impact on the opportunities for distributors to offer a unique product range and/or specialties.

Distributors should focus on SCCs which are able to redesign their role in the supply chain. A clear strategy, technical know-how and financial strength are the required characteristics to achieve this. Distributors and SCCs can also create stability by creating contract forms which are designed to reduce price risks. Until today, both sectors have primarily engaged in sub-optimization. Advanced purchase contracts can both mitigate price risks for both SCCs and distributors, while providing an incentive to SCCs to share their true demand forecast information.

**SSPCs**

Overall, SSPCs engage much more in actions that cause the bullwhip effect, hence limiting variability is closely linked to the limitation of the independent variables that cause this phenomenon. The existence of inventories in the sheet supply chain is an important condition for SSPCs to cause an increase in demand variability.
Steel sheet distributors can reduce the variability of the flow of products within the supply chain in a variety of ways. An important cause for demand volatility is batch ordering, in particular for slow movers. SSPCs engage in batch ordering because large batches have attractive prices. Distributors offer these lower prices because of lower handling and transportation costs. However, batch ordering also has unfavourable consequences for distributors: an increased variability of demand and a decrease in service levels. Due to batch ordering, SSPC are forced to hold larger stocks, increasing their requirement for capital. Literature provides solutions for distributors to perform a larger number of smaller, but cost effective deliveries.

SSPCs have several incentives to engage in long term relationships with distributors. First, high tech processing techniques require a constant quality of input material. Second, end users demand a higher level of price stability. Relying on a single distributor improves the options that SSPCs have to achieve these targets. The automated processes, high tech production equipment and present stock management provide SSPCs with the hardware and software needed to engage in centralizing demand information. VMI could be part of a strategic alliance, in particular for SSPCs focusing on specialization. Steel distributors need to engage in strategic alliances to reduce uncertainty. They can offer new contract forms to their customers. By focusing on revealing the capacity levels in the supply chain and by fixing prices, the buyer’s true forecasts can be revealed. As a result, the matching of the purchasing patterns to the real demand patterns will improve. The dependency on global price developments decreases when a larger volumes are fixed. These contracts must provide clear incentives for SSPCs to commit themselves.

5.5 Recommendations for steel distributors
These outcomes provide steel distributors with the following principal options when it comes to reducing the negative effects of demand variability:

1. Distributors can reduce demand variability in both sectors by offering suitable contract forms, which are aimed at fixing prices, securing availability and sharing risks.
2. Distributors need to focus on tailored solutions as steel processors experience different problem areas, depending on the strategic choices they make and the end user markets they supply.

3. Distributors can reduce demand variability from SCCs by forming strategic alliances, designed to generate long-term advantages. The most important condition to form alliances is mutual trust.

4. Smaller SCCs would benefit from an increased level of standardization of sections as this decreases the risk of obsolete material. Inventory management of distributors would improve because the number of slow movers will decrease and reduced overlap will improve the reliability of demand information.

5. Most SSPCs engage in batch ordering to minimize material prices. Distributors can reduce demand variability by designing the supply chain with the purpose of effectively performing a larger number of smaller deliveries.

6. SSPCs have more incentives (dependence due to the use of special qualities, long term contracts and constant material quality) and are better equipped (hardware, software and inventory management) to engage in strategic alliances. Price stability is also an incentive for SSPCs to enter into an alliances.

5.6 Further research

Demand variability will not be the only future challenge for Dutch steel processors and distributors. A recent article published by the association of Dutch steel distributors (Staalfederatie, October 2010) confirms the supply chain is in a period of transition and that that steel distributors need to redefine their role.

Specialization, supply chain integration, prefab manufacturing and sustainability are already becoming important topics. The global reserves of many raw materials will be exhausted in the next decade. The industry will have to use these reserves wisely. It is essential for the Dutch steel industry to find opportunities to improve the efficiency of the supply chain in order to decrease system wide costs and increase the focus on customer demands. The quality of information technology will further improve and will
increasingly be applied in the sector. As a consequence, cooperation in the supply chain will increase.

Demand will show an overall slow and steady decline in the future. Steel distributors must search for partners in the supply chain to strengthen their position and to reduce the unfavourable consequences of demand and price variability. Today, literature research reveals little information on how these challenges can be met. Further research is necessary to establish the optimal design of the supply chain and the available solutions for distributors to contribute to this process.
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<td>Bullwhip effect</td>
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<td>My company can easily find alternative suppliers</td>
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<td></td>
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<td>My company runs MRP periodically</td>
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<td>My company uses production smoothing</td>
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<td>The cost for steel ranks as .. % of sales price</td>
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