Substitute products in the automotive steel sheets market according to sustainable innovations in technology

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Abstract: Steel is one of the most consumed materials in the automotive industry, and as such the steel industry has played an important role in the supply chain management of automakers. This study considers various substitutes for steel products in the automotive body sheets market according to sustainable innovations in technology. It emphasizes the importance of steel mill relationship management with the technology management of automakers, in order to link market needs with technology development. Product replacement according to a revolution of technology is considered by using advanced technologies such as high strength steel and tailor welded blanking, and the development of value-added automotive steel products with their market behaviours is studied based on three models of product life-cycle, adoption-diffusion and technology applications spectrum.

Keywords: substitute; steel industry; automotive body sheets; technology innovation; automaker; market; relationship; management.


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1 Introduction

As key national industries, the automotive and steel industries are closely related from the perspectives of forward and backward linkage effects and of relative importance in the gross national income (GNI) and for the labour population. Governments support these industries politically and protect their domestic markets from foreign competitors and new entrants through various policies such as safeguards and the import quota system and with free trade agreements such as the EU and NAFTA. The regional production of
automotive vehicles recorded in the year 2001 was about 36% in Europe, about 32% in Asia and about 28% in North America. China’s automotive industry is now emerging with about a 12.8% production increase in 2001 compared with the previous year. However, it is still in pursuit of localisation through the proactive acquisition of advanced technologies from the world’s leading automakers.

Steel is one of the most consumed materials in the automotive industry, and especially flat products such as hot rolled, cold rolled and coated steel sheets account for about 80% of steel products consumed by automakers. Approximately 14–15% of the domestic shipments of the US steel mills was towards automakers during the last ten years. However, lightweight materials such as aluminium, magnesium and plastic are rapidly substituting for steel as automotive body sheets. For instance, steel in the automotive body weight decreased by about 10.3% points during the last 24 years, that is, from 81.1% in 1973 to 70.8% in 1997, while competitive lightweight materials increased by about 9.2% points from 7.9% to 17.1% [1].

The world’s leading automakers in North America, Japan and Europe have steadily supplied high quality of products from adjacent steel mills over long-term contracts. The major steel suppliers in these regions can be considered to be AK Steel and International Steel Group (ISG) in the USA, Arcelor and ThyssenKrupp Stahl in Europe and Nippon Steel Corporation (NSC) and JFE Holdings in Japan. Since processing facilities and tools involve a high cost of investment, it is not simple to switch to new suppliers or products. Recently, mega-mergers and acquisitions between global automakers are have been taking place worldwide, so that they are stronger in their bargaining power against suppliers. Furthermore, automakers tend to adopt global sourcing, concentrate purchasing with fewer suppliers and expand their outsourcing range. Then suppliers are more responsible for technology innovation as well as the reduction of production costs.

Technology innovation can be classified in to two patterns: radical and gradual innovations. In the case of automotive steel sheets, radical innovations such as hot-dip galvanizing steel (HDG) and electro-galvanizing steel (EG) have resulted in substitutes for cold rolled steel (CR). On the contrary, through gradual innovations such as continuous casting and continuous annealing, improvements in productivity and quality as well as cost reduction have been obtained. Both types of technology innovation have to be performed continuously in order to maintain market leadership.

The diffusion of technology can occur slowly in early phases of adoption because new technologies may not operate efficiently due to inexperience and the initial incarnation of ideas into equipment may be far from ideal (Greenwood 1999). However, technology innovation occurs gradually in the initial learning period, and experience and know-how are accumulated through trial and error. Through learning processes, the production cost decreases, while profits increase with improvement of productivity. According to the diffusion of technology, the market becomes more competitive and less profit is earned. Then, a new innovation in technology with barriers has to be achieved in order to maintain or even expand the market.

This study will consider the substitute of steel products in the automotive body sheets market according to sustainable innovations in technology. In Section 2, the importance of relationship management with automakers will be emphasised, as will be the management of how to connect customer needs with technology development for steel mills. Then, by using a case of tailor welded blanking (TWB) technology, product replacement according to revolutions in technology will be considered in Section 3.
In Sections 4 and 5, the substitute and market behaviours of conventional automotive steel sheets will be analysed based on the three curves of the product life-cycle, adoption–diffusion and the technology application spectrum [3]. Finally, the recent substitution of multi-functional coated products will deal with appropriate business strategies.

2 Relationship management of steel mills for automakers

It is not simple to estimate accurately the speed and impact of market change because a revolution in technology progresses very quickly in a worldwide range, and therefore, various perspectives of marketing should be strategically integrated in order to survive in fierce competition. Figure 1 shows the ten marketing perspectives of Bearden et al. [4] that are applied to the market environment for automotive steel sheets.

Figure 1  Bearden et al.’s ten marketing perspectives for automotive steel sheets

Among Bearden et al.’s perspectives, the customer relationship of steel mills is mostly concerned with the globalisation of the automotive industry. Strategic alliances between automakers and/or suppliers have been performed worldwide in pursuit of economy of scale as well as a share of the risk burden for technology development. The world’s leading automakers preferentially adopt global sourcing, concentrated purchasing and platform unification for reduction of production costs. Furthermore, the modularisation or systemisation of vehicle components activates the partnership of OEMs with tier-1 suppliers. The concept of relationship is based on a close linkage of companies with stable and long-term contracts, with an eventual goal of developing an organic cooperative system in total marketing. In relationship marketing, the customer and its suppliers in mutual trust share related information and pursue common business goals through win–win value chain systems. That is, steel mills can stabilise the volume of sales with accurate demand forecasting, while automakers can develop a stable supply chain from the aspects of both cost and technology competitiveness.
Relationship management can be diversely characterised by the structure of a regional market. As a systematisation of total value for OEMs and suppliers in the globalisation and paradigm shift, the world’s leading automakers are proactively adopting the vendors’ early involvement program at the initial stage of new model development. Instead of conventional quality management systems such as QS-9000, VDA.6, EAQF and AVSQ, automakers in the USA and Europe have currently integrated with a new automotive specification, ISO/TS16949, for global quality management. Figure 2 is the organisational structure required to pursue successfully the strategic technology management of steel mills. Internally, several divisions such as planning & finance, marketing, production and R&D are closely related with their original roles in technology management activities. However, each division could have different points of view with its functional aims or objectives, rather than its corporate missions and goals. Externally, a one–one partnership with major automakers is necessary in a rapidly changing environment because customer requirements through the marketing division should be directly linked to technology development and its commercialisation.

Figure 2  Organisational structure for the strategic technology management of steel mills

As pointed out, any developed technology has to be implemented into mass-production through a proactive and harmonious communication among related divisions and appropriate coordination by a capable leader. In automotive steel sheet manufacturing processes, quality specifications of steel making, hot rolled and cold rolled mills affect both backwards and forwards, and therefore concurrent engineering among processing lines in a steelworks should be performed in strategic technology management.

3   Substitutes for steel products according to technology innovation

Robert M. Solow, a Nobel Prize winner in 1956, described how traditional growth theory dictates that technology progress is not the subject of research from an economic point of view. In contrast, the US economists Paul Romer, Robert E. Lucas, Jr. and Robert J. Barrow suggested the Endogenous Growth Theory in the 1980s, stating that technology progress is an endogenous factor and thus is affected by the amount of capital
to be accumulated. According to this theory, technology progress occurs on an accelerative basis and one technology development makes another easier. With the start of knowledge-intensive industry in the second half of the 20th century, the law of increasing returns came into the spotlight, wherein increasing returns eventually monopolise a market, and the law of diminishing returns was challenged. Although there still exist a lot of difficulties, such as the uncertainty and risk with the huge amount of R&D cost in technology development, a company becomes the one and only supplier with a strong market control power, once it is acquired.

According to the law of increasing returns, the value of technology defined as an endogenous growth engine in a firm shows the shape of a ‘S’ curve as time progresses. While it keeps rising up to a certain time, a competitive technology with a far superior performance is being developed and eventually comes to substitute the existing one. The main technological objectives in the automotive industry are to simultaneously optimise safety, environment protection and energy saving. In order to satisfy customer requirements, globally leading steel mills have developed advanced products such as high strength steel (HSS) or advanced high strength steel (AHSS) as well as new manufacturing technologies such as hydroforming and tailored blank welding. In the conventional manufacturing processes of the automotive industry, a body panel is pressed or stamped from a single blanked sheet. Generally, each panel requires 4–6 stamps with the same number of stamping dies. However, a panel may require different functional properties such as strength, formability, thickness, coated or uncoated format, etc. In such a case, the steel sheets are tailored on the basis of customer specifications, and tailored blanks are welded together using 3-D laser beams. This process produces what are known as tailor welded blanks (TWBs). By using this technology, the manufacturing processes of OEMs can be pared down along with reduction of body weight.

TWB technology was developed in the 1970s and applied to the automotive industry from 1985. There exists some time gap between technology development and the appearance of its commercialised product in a market as shown in the case of TWB. Paul David [5] of Stanford University says in his book titled The Dynamo and the Computer that immediate effects could not be obtained when a steam engine was replaced with an electric one and that it takes time until profits are made. However, its market will grow exponentially as time passes.

Thyssen Fugetechnik in Germany initially started to produce TWB products in 1985 and there were 12 TWB makers worldwide in 2002. Figure 3 shows the TWB growth in European markets during the last ten years, which is exponentially increasing. The future market growth can be represented like the dotted line in Figure 3 according to the assumption of an S-curve. Recently, Baosteel in China made an agreement with Arcelor in Europe for the establishment of a TWB joint venture aimed at operation in 2004. Their TWB products will be supplied to global joint venture automakers in China such as Shanghai Volkswagen, First Auto Works Volkswagen, Shanghai GM, Changan Ford and Guangzhou Honda. Since 1998, TWB investments have been made actively in Asia, and POSCO and Hyundai HYSCO in Korea have participated competitively in TWB facility investments in the recent 2–3 years.
Figure 3  TWB growth in European markets

Figure 4 shows the discontinuity of technologies in the area of automotive steel sheets where a lightweight body is pursued. A conventional blank is a piece of steel sheet with identical mechanical properties. For some additional requirements, such as reinforcement and corrosion protection, other steel sheets are attached using joint technologies such as welding and bonding. Instead of additional sheet attachment, lightweight HSS began to substitute conventional blanks since the 1970s and then tailor welded blanks since 1985.

Figure 4  Technology discontinuity in automotive body steel sheets

If a technology-oriented firm intends to make profits, its innovative technology should guarantee profitability and market growth from the aspects of production cost, quality or performance, compared with the sectors of technology acquisition and facility investment [3]. Through technology management activities, corporate value has to be created so that profit is maximised along with market growth. As shown in Figure 5, conventional blanks are proactively replaced with value-added products such as HSS and TWB with a lighter weight. The lighter the weight of a product, the more satisfied are customer needs and the more growth the market enjoys. And, the more value-added are its products, with high strength and advanced manufacturing skills, the more marginal are the earnings of a firm. Advanced products require more intensive technical support of suppliers for customers, and it makes the relationship of OEMs and steel mills stronger.
4 Conventional substitutes for automotive body steel sheets

This section will consider substitutes for automotive body sheets according to both radical and gradual innovations of steel technology. Automotive steels are mainly composed of flat products such as hot rolled (HR), cold rolled (CR) and coated steels, and these account for about 70–80% of automotive steel products. In the annual steel consumption of Japanese domestic automakers, domestic orders are about 80–90%, while foreign orders are less than 20%. Since automotive outer and inner panels of high value-added products require advanced technical skills, Japanese automakers prefer technically advanced Japanese mills. Figure 6 shows the domestic steel procurements of Japanese automakers during the last 30 years, where steel sheets continuously maintain a level of about 80%. The right side of Figure 6 shows the order trend of HR, CR and coated steel sheets as time progresses. Originating in the mid-1970s, coated products have been growing rapidly in the Japanese automotive market, and their orders have surpassed CR following a revolution of coating technical skills since the mid-1980s.

Figure 7 shows the relative proportions of automotive HR, CR and coated steel sheets in Japan, almost identical in 1988. Until the mid-1980s, the proportion of HR gradually increased by technology developments such as in surface quality development and
formability, and since then it has been maintained continuously at about 35%. The proportion of coated products increased rapidly during the mid-1980s up to the beginning of the 1990s because end-users required high quality and automobile performance. Then, the proportions of HR, CR and coated products stayed in a relatively stable condition as shown in the right side of Figure 7. This phenomenon can be explained with the concept of product life-cycle according to a revolution of technology.

Figure 7  Procurement proportions of domestic automotive steel sheets in Japan

The automotive steel sheet market activated the innovation of steel technology with environmental effects such as legal regulations for vehicle emissions and the oil crisis in the 1970s. At the same time, revolutions of technology such as hot dip galvanising and TWB stimulated the market to replace conventional products. Consequently, technology innovation and market variation affect each other in a chain as shown in Figure 8. For the satisfaction of automobile end-users, automakers require some characteristics of steel, such as strength and being lightweight, with a minimum life span of six years in cosmetic corrosion and twelve years in perforation corrosion. Both gradual and radical technology innovations can provide improvement of productivity and quality and then change the market structure.

Figure 8  Chain of automotive steel sheet market and its technology innovation

Following the localisation of the Japanese automotive industry in the 1950s, steel mills developed core technologies with facility investments such as in LD furnaces and continuous casting in upstream lines and continuous annealing and surface treatment in downstream lines. Figure 9 summarises technology goals and managerial environments in the automotive business in each decade [7]. Japanese steel mills focused on the deep drawing quality of products from the 1950s to the mid-1960s and HSS and coated steel
products until 1990. Currently, in order to lower production costs, several technologies such as TWB and hydroforming are being adopted.

Figure 9  Key technologies in the automotive steel sheet market

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5  Product development and market behaviour for automotive steel sheets

In order to study new technology developments and market behaviour, analytical tools such as the product life-cycle and adoption–diffusion model can be used, which were developed by the US Department of Agriculture in the 1930s. The product life-cycle shows the path of a product’s growth and maturation, and the adoption–diffusion curve explains customer behaviour as the market grows. The technology application spectrum (TAS) can be used to find the relationship with finance such as variations of price, margin and capital investment. Three curves are correlated in a time domain as a simple qualitative forecasting tool for product development, markets, finances and operations [3]. These three curves for automotive steel sheets will be considered as follows.

5.1  Product life-cycle for automotive steel sheets

As the main functional properties of automotive steel sheets, anti-corrosion and drawability will be considered here. Figure 10 shows the life-cycle curves of automotive HR, CR and coated steel sheets. CR substituted for HR until 1965, and then the life-cycle of CR started the decline following the development of HR and coated products. The life-cycle of coated products continued the introduction by the innovators in the early 1970s and soon experienced growth after being accepted by the early adopters and some of the early majority.

Figure 10  Life-cycle curves of automotive steel sheets
By the early 1990s, coated products rapidly replaced CR from the same levels as in 1988 and maintained a relatively constant degree of about 60% compared with 40% of CR. Currently in the Japanese automotive industry, the life-cycle of coated steels is between maturity and decline. However, automakers in North America and Europe keep approximately 80% coated products vs. 20% CR, and the portion of coated products vs. CR is still increasing. A few models, such as Volkswagen’s Golf and GM’s Opel Astra, adopt 100% coated steel sheets, and it is expected that European automakers will continuously raise the level to 85–90%.

5.2 Adoption–diffusion curve for automotive steel sheets

As shown in Figure 10, a new technology is adopted in a predictable bell-shaped curve. The adoption–diffusion model classifies automakers into five groups according to the time of adoption: the innovator, the early adopter, the early majority, the late majority and the laggard. The early majority for coated products was fully on board from 1980 to 1988, and coated products were on their way to a large market. Then, the purchasing volume for coated products rose, and their prices and margins fell. The late majority adopted coated steels. Different price policies had to be applied to each group. The innovator or early adopter places stress on the importance of performance, rather than on price, and therefore, it is essential not to reduce the profit due to low prices and not to damage the brand image. When the majority begins, price adjustment is a core strategy, and this is one of the reasons why prices fall as time passes, as shown in Figure 11. Some other strategies may be improvement of productivity and cost reductions through technology progress. The prices of steel sheets rose in 1995 and 2000, and therefore the shares of both HR and CR increased while that of more expensive coated products decreased.

![Figure 11 Variation of Japanese export prices for steel products](image)

5.3 Technology application spectrum for automotive steel sheets

As the value of automotive steel sheets sequentially moved to the regions of unique, exotic, specialty and commodity in a time domain, more competitors entered the market and the prices of products went down with a lower margin. In order to increase profits, companies have had to perform value-addition activities through both radical and gradual innovations of technology.
Steel mills have to focus on only one region in the TAS because corporate and technology strategies with their corresponding activities are different in each region [3]. Japanese steel mills set the regions of unique/exotic and specialty as the target position and commercialised coated steel technology at an early stage. The best strategy for the unique/exotic and specialty is to prevent or delay the technology progress and to create continuously high value-addition applications. On the contrary, new entrants or followers in the world try to standardise a specification of coated steel sheets and to commoditise these products by cost reductions and price cutting.

6 New substitutes for value-added products in the automotive steel sheet market

According to the proactive outsourcing policy of OEMs to tier-1 suppliers, steel mills are taking over some assembly processes of OEMs to the maximum extent, including component processing. The world’s leading steel mills in Europe are currently focusing on the innovative technology of organic coatings such as in producing pre-sealed, pre-primed and pre-painted steels in order to improve the formability and corrosion protection (lifelong rust warranty) and to simplify the painting processes of OEMs. R&D activities in this area will be conducted as shown in Figure 12, and eventually OEMs will adopt pre-painted steel sheets in the near future, which will eliminate further in-house painting processes. Western European steel mills such as ThyssenKrupp Stahl, Arcelor, Salzgitter and VoestAlpine are globally leading this research area, with major customers such as Daimler, Chrysler and Volkswagen in Germany. It is expected that the market for organic coating products will grow exponentially, which is similar to the case of TWB.

Figure 12 Role transfer of OEMs to steel mills in the automotive steel sheets market

Figure 13 shows the phenomena of product substitution in the automotive steel sheet market by simultaneously using the product life-cycle, technology adoption–diffusion and the TAS. In the Japanese automotive steel sheet market, conventional coated products started to substitute CR in the early 1970s, and the current life-cycle of these products is on the decline with the late majority or the laggards. In the TAS, coated products have become a commodity and Japanese steel mills are pursuing the creation of high value-added applications in order to prevent further commoditisation.
In the meantime, in the late 1990s European steel mills started to develop organic coated products such as pre-sealed and pre-painted steels for substitution of conventional products. As shown in Figure 13, these multi-functional steel sheets have already started to replace coated products in the Western European market, although in terms of the unique or exotic of the TAS. It is expected that these products will gain market growth with remarkable speed. Therefore, technically advanced steel mills have to maintain their current position as long as possible, with a high technology barrier. In contrast, other mills have to standardise their specifications and commoditise these new products through gradual innovation of technology for cost reduction.

7 Conclusions

As steel is one of the most highly consumed materials in the automotive industry, this study considered the substitution of steel products in the automotive body sheet market following sustainable innovations in technology. It emphasised the importance of steel mill relationship management for automakers, in order to connect customer requirements appropriately with technology development. The market behaviour of both conventional and new automotive steel sheets was analysed using the models of the product life-cycle, adoption–diffusion and the TAS.
Consequently, steel mills have to prepare differentiated business strategies and supply chain management systems for automakers in a rapidly changing global environment. The market structure of their key products and the future direction of technology innovation should be precisely forecast in the mid and/or long term in order to maintain or even expand their major markets. However, one-to-one correspondence with automakers should be optimised because it raises production costs, and therefore, mass customisation with low costs has to be pursued along with standardisation, simplification and systemisation of market needs.

It is also required that the value chain create the profitability and market growth be developed at an early stage through strategic technology management with both gradual and radical innovations of technologies. Then, the world’s leading steel mills with advanced technologies can maintain their market positions as long as possible. On the contrary, new entrants and followers have to standardise their specifications and commoditise high value-addition products with technology barriers.

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