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WINDS OF CHANGE ARE BLOWING

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The Fourth Industrial Revolution is bringing massive changes to mankind through accelerated integration of traditional industries and ICT. The Internet of Things (IoT), Big Data, and Artificial Intelligence (AI) are forcing traditional industrial structures to rapidly change. The scale, scope, and complexity of these changes will be unprecedented. Steelmakers are also actively developing advanced technologies to respond to the massive paradigm shift. The leading steel mills will customize technologies such as AI and virtual factories and apply them to the production sites. They will strengthen integration along value chains by connecting clients and suppliers through smart factories.

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The Fourth Industrial Revolution: The Winds of Change Are Blowing in the Steel Industry

Realization of The Fourth Industrial Revolution in Steel Plants

Energy
Production
Safety & Environment
Quality
Facility
The Fourth Industrial Revolution: The Winds of Change Are Blowing in the Steel Industry

“Mastering the Fourth Industrial Revolution” was the official theme of the World Economic Forum, held in Davos, Switzerland early this year. The news from this forum was that boundaries between the digital, physical, and biological spheres will disappear, and the convergence of technologies will be expedited, ushering in a new era of unprecedented experiences for humanity.

We are already experiencing enormous changes. With accelerating technological innovation across industries, the landscape of traditional industries is changing, as are the value chains and market players of traditional industries. The steel industry is no exception. What fundamental changes can we anticipate? How will they affect manufacturing, and what must the steel industry do to prepare?

Traditional industries on the brink of collapse

Over 100 years elapsed between the First Industrial Revolution, which was triggered by the advent of steam engines, and the Second Industrial Revolution, which was characterized by the use of electricity and conveyor belts. Another 60 years passed before the Third Industrial Revolution, which was brought on by the invention of personal computers and the Internet. Now, after only 20-30 years, the world is facing the Fourth Industrial Revolution.

Change is ever-accelerating and its impact is ever-stronger. In the midst of the Fourth Industrial Revolution, which is characterized by big data, the Internet of Things (IoT), artificial intelligence (AI), virtual reality/augmented reality (VR/AR), and 3D printing, competition in technological innovation is breaking down every aspect of traditional industries at an alarming speed.

First, conventional labor structures are collapsing. About 3-4 years ago, AI-produced earthquake and weather news stories appeared in the Los Angeles Times. Although this was much talked about, the news stories were comprised only of simple facts. At that time, AI was a convenient tool and a friend to human journalists pressured by deadlines. But now, AI is replacing human
The Fourth Industrial Revolution: The Winds of Change Are Blowing in the Steel Industry

journalists. AI is capable of writing pro baseball reports, using more analytical and descriptive language than human journalists, and broadcasting games through SNS. In the financial sector, AI is writing analysis reports and making investment decisions. Last year, in China, AI wrote a thousand-word report that would have taken a human expert several days to prepare in just over a minute. In Korea, AI fund managers are making investments.

AI has a significant presence in manufacturing as well. Baxter, a robot that costs less than USD 30,000, works 24/7 in manufacturing plants in various fields. Kiva robots stack and pick up products in Amazon warehouses. The World Economic Forum predicts that 4.759 million clerical and administrative jobs, and 1.609 million manufacturing and production jobs will be lost in the next five years. The traditional labor structures of many industrial fields have begun to collapse.

Second, industrial structures are breaking down. Traditional companies are losing their footing due to the appearance of new competitors equipped with innovative technologies and differentiated business models. The most dramatic changes are unfolding in the automotive, energy, and finance industries.

Internal combustion engines are giving way to electric vehicles (EVs) and self-driving cars, which can be described as smart devices with wheels. In one blow, this shift will devastate the long-established automotive parts supply chain, which has been centered on engines and transmissions. This could happen in only a few years, not in the distant future.

The traditional structure of the energy industry is also crumbling. The spread of decentralized energy generation is destroying the current centralized generation paradigm. Grid parity is projected to occur by around 2020, meaning that a developing technology will produce electricity for the same cost as traditional technologies. This indicates that the traditional structure of the energy industry is bound to change. Massive transformations have already begun in Germany, Australia, and the USA.
In the automotive industry, for instance, the value of data such as driving patterns and locations, may exceed the value of cars, and provide much greater opportunities to car makers because a car becomes a source of various customer data and a channel for delivering new services to customers.

The current finance industry is also faltering. The emergence of mobile payment providers, such as Samsung Pay and Apple Pay, is upsetting the traditional payment market structure. Internet-only banks and cloud funding are shifting the financial paradigm. In China’s payment and lending markets, the share of mobile and Internet firms exceeds that of traditional financial institutions.

Destruction of industrial structures will spread to all industries. The established rules are already changing, and the hegemonies that have led industries are losing ground. Companies from different fields are making inroads and challenging traditional industries.

Third, traditional methods of creating value are also being destroyed. The common expectation of what costs money is being overturned. Energy, often regarded as paid goods, can become free. In the USA, Tesla provides its customers with free charging through its vast network of “supercharger” stations. In Japan, a telecommunication company branched into the electricity business, and bundled telecommunication and broadcast services with electricity. This means that energy will potentially become free of charge, just like e-mail and video streaming.

The price of an item with zero marginal cost moves toward zero. With the rise of the shared economy, which links the information of suppliers and customers on one platform, the concept of ownership is changing. This changes the understanding of value and upends traditional business models. Airbnb and Uber show how it is possible to enter the accommodation and transportation businesses without investment in fixed assets such as hotels and cars, disrupting the traditional way of creating value.

In the era of the Fourth Industrial Revolution, intangible value exceeds tangible value. In the automotive industry, for instance, the value of data such as driving patterns and locations, may exceed the value of cars, and provide much greater opportunities to car makers because a car becomes a source of various customer data
and a channel for delivering new services to customers. This explains why Google has paid USD 3.2 billion for a household device maker, Nest. Its true value lies not in its hardware, but in the data that the hardware collects from each household.

Companies like Tesla, Google, and Amazon, are branching into traditional industries. But, instead of following the conventional way of doing business, they introduce a new business model, weaponizing data and software. Who will win this competition?

How do countries prepare for the future of manufacturing?

The rapid change of the traditional industry and disruptive advances in technology is threatening the very survival of countries and companies built on manufacturing.

For industrialized countries, which have long been suffered from high labor costs, stagnant production, and decline in the labor force, the Fourth Industrial Revolution is a breakthrough, and an opportunity to take the leadership in the future.

In the USA, under President Barack Obama’s Reshoring Initiative, the Advanced Manufacturing Partnership (AMP) was launched in 2011, and the National Network for Manufacturing Innovation (NNMI) was issued in 2013 to enhance manufacturing capabilities by supporting collaboration between industry and academia. In October 2015, Washington released the “New Strategy for American Innovation” to regain U.S. technological innovation leadership in the global manufacturing market by increasing investment in R&D, mainly in nine areas of strategic opportunity: advanced manufacturing, precision medicine, the BRAIN initiative, advanced vehicles, smart cities, clean energy and energy efficient technologies, educational technology, space, and new frontiers in computing.

Germany unveiled the High-Tech Strategy 2020 in November 2011, which identifies future projects, including Industrie 4.0. The underlying

### Keywords for National Policies Regarding the Fourth Industrial Revolution

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<th>Germany</th>
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<td>Industry 4.0</td>
<td>Advanced Manufacturing</td>
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<td>Cyber Physical System (CPS)</td>
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In the future, products and services must move beyond ready-made customization. Extreme flexibility is required in the production process in order to satisfy individual needs without compromising cost. Mass Personalization is the future of manufacturing in the Fourth Industrial Revolution.

The concept of Industrie 4.0 is to integrate manufacturing and ICT via IoT, 3D printing, and cyber physical system (CPS) for networked and intelligent production facilities. All processes concerning raw materials, production, logistics, service, and products are connected to networks through embedded systems and controlled through CPS. By setting these technologies as national standards, Germany is showing its determination to assume technology leadership in the Fourth Industrial Revolution.

In response to the U.S. Advanced Manufacturing Partnership and Germany’s Industrie 4.0, Japan’s strategy is to improve manufacturing competitiveness centering on its relatively competitive robotics field. To this end, Japan announced the New Robot Strategy in 2015, which aims to robotize objects so as to greatly increase the utilization of robotics, and to utilize the data produced to create new wealth, ultimately contributing to solving social problems and increasing competitiveness in the manufacturing and service sectors.

China is preparing for the Fourth Industrial Revolution by two separate initiatives: “Made in China 2025” and “Internet Plus.” The “Made in China 2025” plan is a strategy to comprehensively upgrade Chinese industry to achieve qualitative growth, with a view to transforming China from a manufacturing giant based on cheap labor costs and cost competitiveness into a global manufacturing power backed by technological innovation. Recognizing the integration of the Internet and traditional industries as a new engine for industrial development, China announced the “Internet Plus” action plan, which aims to build the world’s largest Internet platform, and carries out smart manufacturing development strategy through the integration of manufacturing and Internet technologies.

The intensifying competition in technological innovation among companies and countries is rapidly reshaping the landscape of manufacturing. The concepts of customers and their demand are being redefined. Production methods, company structures, and value chains are all changing.
Changes for consumers: the era of “mass personalization”

Consumers want products and services tailored to their needs, but diversity means cost to companies. In the past, companies tried their best to reduce production costs through standardization and mass production. As the satisfaction of customers’ various needs has become a key element of differentiation, companies have segmented and targeted markets and customers, and pursued customization to give more choices to customers. For example, customers are offered ready-made clothes in more colors and sizes.

In the future, products and services must move beyond ready-made customization. Customers are no longer mere segments and targets. They define and select products and services to meet their individual needs. All customers will be able to wear personalized clothes, not ready-made clothes. What matters is cost. Variety should not compromise cost. Extreme flexibility is required in the production process in order to satisfy individual needs without compromising cost. Mass personalization is the future of manufacturing in the Fourth Industrial Revolution.

Changes for suppliers: dynamic intelligence, real-time enterprise, and servitization

Production sites need fundamental change in order to produce products tailored to each consumer. This is a transformation from a mass production-based, centralized production system to a decentralized, unmanned autonomous system that provides extreme flexibility.

In a centralized production system, processing data are entered into a central controller and production facilities process materials as programmed. However, in a decentralized production system, processing data are embedded in materials and production facilities. After collecting information from the surrounding environment and sensors attached to the product, facilities recognize the current situation and start operation autonomously. This enables precise control of each process and part.

This new dynamic alters the age-old concept of automation. Central control, fixed products, and scheduled processes become distributed control, designed products, and flexible processes. The automation of the past was based on static intelligence, by which facilities merely fulfilled the orders given, but the automation of the future is based on dynamic intelligence, by which facilities react to changing situations.

Siemens’ Amberg factory adopted radio-frequency identification (RFID) and barcodes for every product and component. Through machine-to-machine (M2M) communication using over 1,000 sensors and scanners, the factory processes and integrates 50 million pieces of data per day. It manufactures more than 1,000 types of 12 million programmable logic controls (PLCs) in an average year, and still has only 11 defects per million (Production quality of 99.9988%).

A second change is the transition into real-time enterprises based on the integration of business logic and manufacturing logic. As
In addition to being flexible, a production system needs to ensure the visibility of real-time operational data and provide insight for better and faster decision-making along the value chain.

Markets become more volatile and product life cycles become shorter to meet rapidly changing customer needs, it is important how fast and accurately corporate can meet time-to-market goals. In addition to being flexible, a production system needs to ensure the visibility of real-time operational data and provide insight for better and faster decision-making along the value chain, from product design, sourcing, and supply to logistics, distribution, and sales.

To this end, companies are integrating business logic and manufacturing logic. By integrating manufacturing logic, which controls production processes, and business logic, which manages production schedules, material/inventory management, and logistics, companies strive to minimize time-to-market. By ensuring integrated data visibility in all product life cycles, Siemens oversees all processes of product planning, design, production, and facility management at a glance, ultimately halving time-to-market.

A third change is the expansion of value chains beyond manufacturing to remote-control-based servitization. In general, value creation in manufacturing is completed upon release of a product. Customer service used to be considered a cost by corporations. Now the release of a product is the start of the sale of new services. Corporations can collect customer information and usage patterns from sensors attached to products.

GE has launched Predix, a cloud-based platform for industrial internet applications, that combines people, machines, big data and analytics. Predix analyzes and manages data being generated from purchase to customer service as sensors are attached to everything from aircraft engines to medical equipment. For example, the platform as a service (PaaS) helps jet engines fix themselves and supports the operation of power plants in remote places. It also helps distribute and process data flowing out of medical imaging systems.

The steel industry in the fourth industrial revolution

The Fourth Industrial Revolution is also gaining
ground in the steel industry, and new changes are becoming apparent. One change is the integration of digital networks in value chains. Plants, companies, and even the entire steel industry can be integrated into a single digital ecosystem.

Germany’s ThyssenKrupp is building an integrated digital system to allow real-time information on orders and production to be shared among the company, suppliers, and client companies. For example, Huttenwerke Krupp Mannesmann (HKM), a supplier of hot-rolled strip steel to ThyssenKrupp Hoesch Hohenlimburg, shares order and production information in real-time with ThyssenKrupp. The two companies coordinate in advance the order of production processes and timing of deliveries, minimizing waste in production and swiftly responding to customer needs. By expanding the scope and depth of digital integration, ThyssenKrupp plans to reduce time-to-market to 24-28 hours for all of its plants.

Tata Steel Europe is also seeking digital integration of logistics processes to allow clients to monitor scheduling of shipments in real time. For example, a client at a steel plant in the Netherlands is provided with information on the location and arrival time of a vessel loaded with HR steel products, allowing the company to achieve optimal inventory management.

The Fourth Industrial Revolution is spreading throughout the steel industry. Tata Steel is planning to digitalize all transactions between its steel plants and customers within two years. It also plans to combine information networks with Klockner, the largest steel trader in Europe. The two companies already share order and purchase data for the UK market, and they plan to expand the scope of integration to other European countries and the USA.

Another change is the trend toward Amazon-like, online-based steel trading platforms. Klockner will build an online transaction platform by 2017. If the platform is successful, the traditional steel trading structure will face a revolutionary transformation.

In a traditional steel market, steelmakers stock inventory and await orders without knowing exact demand. Inventory is a burden on traders. If a mechanism that drastically reduces inventory burden and strikes a balance between demand and supply, an Amazon of the steel industry is foreseeable.

Through its Internet transaction platform, Klockner shares not only its own product information, but competitors’ product information, with a view to increasing transaction efficiency and cost transparency, and eliminating inefficiency in the steel trading structure. The company anticipates a reduction in net working capital of 10%, and savings of EUR 100 million. It hopes to handle more than half of sales through the transaction platform by 2019.

China is also building online steel transaction platforms. Baosteel Group established the Shanghai Steel Trade Center in 2013, and developed it into steel e-commerce platform, called "Ouyeel" in 2015. Shagang Group built its own steel e-commerce platforms, Jiulong Online, in 2014.

This trend shows that information in the value chain of production, distribution, and con-
Consumption is gradually being integrated. In the near future, it is possible that all information on supply and demand of steel will be open to every producer and customer.

Still another change is the advent of “digital genome map” of steelworks. Herein lies the key to the steel-making process in the Fourth Industrial Revolution. This is the heart of POSCO’s vision of the future of steel plants.

There is a big difference between the assembly process for producing automobiles and the continuous process for making steel. It is very difficult and expensive to apply a decentralized, unmanned autonomous system, which is useful in assembling components, to the continuous process of steel, which involves liquid steel at high temperatures moving at high speeds. As the share of labor cost is relatively low in the steel-making process, automation will not bring tremendous benefits in the short term. Furthermore, the steel-making process is mostly automated because it handles heavy raw materials and equipment. What then is the vision of a future steel plant set by POSCO, the largest steelmaker in Korea?

The answer is the development of the “data genome map” based on data and software. The Human Genome Project aims to determine the sequence of the three billion chemical base pairs that make up human DNA, eventually allowing personalized diagnosis and disease prevention. This work seeks to understand the substance of life and unlock hidden potential. A smart steel factory mimics this idea, aiming to collect and
analyze all microdata generated in the production process, and determine the cause of every event. By identifying the exact cause of quality and production issues, and reviewing the status of facilities, steelmakers will be able to solve chronic problems and create new value.

Every aspect of a steel plant, including production, facilities, energy, environment, safety, and quality, is subject to a smart factory. POSCO envisions a steel plant that can sense, analyze, and control its conditions, just as a human can feel, think, and respond. POSCO’s smart factory project, currently taking place at Gwangyang plate plant, will gradually be extended to all production areas.

What must the steel industry consider for the future?
The Fourth Industrial Revolution seems to be just around the corner. The steel industry is not exempt from its effects. It is unknown what calamities might befall the industrial structure and value chain of the steel industry. Are there defense mechanisms for survival?

As stated earlier, the core of the Fourth Industrial Revolution is data and software. GE has a long history and tradition as an automation company in power generation and energy, but it has declared itself to be a software company. Siemens invests in solutions that integrate data and software for all of a company’s product lines. In the automotive industry, more than half of BMW’s R&D staff are software engineers.

Likewise, a steel company in the Fourth Industrial Revolution might need to become a “software engineering company that produces steel,” not a “company that buys and uses software well.” It may sound odd that a steel company needs to become a software engineering company. However, what actually increases productivity, determines the quality of products, and ensures that facilities work properly is not visible hardware, but the engineering and processing knowledge behind it. Software is not merely algorithms and code, but the embodiment of this knowledge.

The steel industry creates profits by selling steel products. However, the real value is in data and software. In order to properly respond to the Fourth Industrial Revolution, steel companies must first understand the value of these intangibles and make the necessary investments. Dieter Zetsche, Chairman of Daimler, gave the steel industry something to think about when he said that mobility will be fueled by software, not by gasoline.
Accelerating Digital Transformation with Smart Factory to Unlock New Value: Case of POSCO

The Fourth Industrial Revolution is bringing massive changes to mankind through accelerated integration of traditional industries and ICT. The Internet of Things (IoT), Big Data, and Artificial Intelligence (AI) are forcing traditional industrial structures to rapidly change. The scale, scope, and complexity of these changes will be unlike anything mankind has experienced. It is no coincidence that new startups such as Google and Tesla have outpaced traditional market leaders such as IBM and GM. This is a sign that the time has come for companies to move beyond the limitations of traditional practices and seek innovative transformation.

Manufacturing plays a fundamental role in the economy, accounting for 16% of the world’s GDP and 62 million diverse jobs. Since the start of the Industrial Revolution 200 years ago, manufacturing has changed the world through relentless advancement in the automotive, chemical, machinery, electronics, and materials industries. There is no doubt that manufacturing will continue to lead technological innovation in the future. Products that will totally change our way of life are continuing to emerge: electric vehicles, self-driving cars, drones, and humanoid robots.

At the heart of the Fourth Industrial Revolution, manufacturing is poised to shift from “traditional” to “smart” through integration with ICT. Leading global companies are already seeing new growth opportunities through breakthrough innovations. General Electric is moving away from its core financial business towards smart manufacturing under the name “Industrial Internet.” Siemens’s Amberg factory has significantly reduced defect rates through IoT technologies, and boasts the world’s best production quality rate at 99.9988%.

POSCO, one step closer to smart factory
In the face of the great paradigm shift brought on by the Fourth Industrial Revolution, many Asian steelmakers are taking preemptive measures to maintain competitiveness and contribute to the advancement of manufacturing. POSCO is also
one of the leading global steelmakers in this arena.

POSCO has been working diligently to adapt to this paradigm shift with the Smarter POSCO mandate, not only to continuously reinforce the competitive edge of its core business, but also to contribute to the advancement of manufacturing industries. The Smarter POSCO mandate calls for creating new, differentiated value through digitalization and intelligence to unlock potential value. Digitalization involves storing, analyzing, utilizing, and emulating the data generated by people, products, assets, and operations. Intelligence harnesses the power of advanced machine learning technologies to enable machines to understand, execute, and improve best practices.

Encompassing the goals of the Smarter POSCO mandate, POSCO defines smart factory as an intelligent factory that senses, analyzes, and controls itself by closely investigating and analyzing production processes using ICT to optimize production, thereby reducing costs, eliminating defects, and minimizing downtime.

In concrete terms, a smart steelworks is a facility that gradually evolves through “smart sensing,” “smart analytics,” and “smart control.” Smart sensing means collecting, translating and connecting data from production sites in real-time, increasing data’s visibility. Smart analytics predicts the status of production processes, that is, the flow of products on the factory floor and the conditions of manufacturing assets, based on the integration of technological (metallurgical) theory, expertise, and big data analysis. Smart control means that intelligent machines learn best practices and optimize production.

The world’s first continuous-process steel plant model

POSCO’s Gwangyang Steelworks produces plates for ships and offshore structures. The factory houses integrated processes for steelmaking, continuous casting, and rolling. In formulating smart factory for steel manufacturing, the following indus-
The Fourth Industrial Revolution has already started and is expected to have a great impact on the survival and development of companies. Steelmakers will strive for long-term innovation to realize smart factories by interconnecting data across production operations, quality and maintenance, upstream and downstream production processes, followed by lengthwise alignment of material-to-final product data.

First, it is difficult to determine the root cause of defects in plates by tracing processes because the physical properties of steel change when molten steel solidifies into plates during the continuous casting process, and plates are frequently cut, flipped, and rotated. Second, adjusting or changing upstream and downstream production processes that are online is costly and difficult. For example, all materials are scheduled to go through production routings and steps in a predetermined order. If trouble occurs in the middle of a process, former processes might be suspended until the problem is solved. Third, various materials are processed in the same facility, and a number of facilities and production methods are involved in making one kind of product, making it difficult to find the exact cause of a problem.

POSCO tailored Germany’s Industry 4.0 approach to meet industry-specific requirements with the following refinements: 1) Converted academic and conceptual theories into practical, applicable actions at the shop floor level; 2) adopted a value-centered, outcome-driven approach aligned with relevant policies; 3) integrated domain knowledge with information and communications technology, rather than simple information technology-driven implementation; 4) employed an evolutionary approach rather than a big-bang approach, and 5) flexibly adapted strict Industry 4.0 standards that made sense for deployment at the shop floor.

Here are the details and major outcomes by phase of the smart factory at Gwangyang Steelworks.

1. Selection of smart factory projects
In order to increase global competitiveness and maximize customer value, POSCO developed a mid- to long-term vision for the Smarter POSCO mandate. Initiatives were then derived in the
areas of production operation, quality, maintenance, safety and energy. New ideas were born through cooperation between experts in steel, R&D, and IT, and were given shape in integrated projects involving IoT technologies focusing on sensing, analytics, and control.

Feasibility and potential outcome were among the high priorities in the selection of projects, with goals including quantification and automation of work that used to depend on experience, combined analysis of interconnected processes, utilization of forecasting and prediction models, and expansion of autonomous control.

2. Development of the “digital genome map” to tackle challenges of smart factory initiatives

POSCO undertook an extensive, thorough assessment of data residing not only in production control systems, e.g. PLC/DCS, but also in business systems such as ERP and MES, as well as the data generated by individual sensors installed on production machines. This rigorous exercise was geared towards the following: 1) identifying data likely to impact production operation and quality that had not been captured, stored, or used (structured/unstructured and macro/micro data); 2) standardizing descriptions and attributes of about 60,000 data entities to ensure that all stakeholders involved have a common understanding; and 3) charting out the digital genome map of steelworks by interconnecting data across production operations, quality and maintenance, upstream and downstream production processes, followed by lengthwise alignment of material-to-final product data.

To achieve this goal, POSCO has made full use of microdata on manufacturing, where previously we used only 6% while discarding the remaining 94%. Additionally, we have collected new, additional data using IoT technology.

In cases of customer claims, it is now possible to quickly and easily trace the exact point where a defect occurred, all the way back to raw materials. An issue can be addressed before it carries into the next process and the cause of a previous process’ issue can be resolved in the middle of production.

3. PosFrame—POSCO’s smart factory platform for continuous process industries

Generally, a software platform is common software where various applications can be developed and serviced. A smart factory platform works as a software substructure that supports smart sensing, smart analytics, and smart control to realize a smart factory.

PosFrame is POSCO’s purpose-built platform
Generally, a software platform is common software where various applications can be developed and serviced. A smart factory platform works as a software substructure that supports smart sensing, smart analytics, and smart control to realize a smart factory.

for process industry applications. It empowers POSCO to: 1) apply the digital genome map to production operations through high-speed collection and inter-connection of structured/unstructured and macro/micro data; 2) rapidly convert smart factory initiatives in domains such as production operation, quality, maintenance, safety and energy into applications with the same ease and speed as building and deploying apps for smart phones; 3) leverage a common platform to adopt emerging technologies, including IoT, big data, and deep learning, which are required for smart factory implementations at the enterprise level; and 4) cost-effectively roll out the smart factory model to other similar factories with standardized, re-usable software components. In the future, POSCO will continue to adopt new ICT for this platform and blend it with global best practices.

4. Smart factory project execution and results sharing

POSCO ran pilot projects to validate business cases and to secure success stories before initiating full-blown smart factory projects. The experience of each preliminary project was applied to the next project, leading to a continuous evolution and development of technologies and experiences. Success cases were replicated at similar plants in order to reproduce outcomes.

The smart factory plant, scheduled to be completed in 2017, seeks to change maintenance, operations, quality, safety and energy as follows:

1) Maintenance: Pre-scheduled and regular maintenance and repairs of defects will be replaced by predictive maintenance that finds defects in advance.

2) Operation: Pre-scheduled production will be replaced by real-time, adaptive production, resilient to changes in demand, quality, and maintenance status.

3) Quality: Reactive quality control will be replaced by real-time, on-the-spot quality control.

4) Safety: Worker safety has historically depended on physical barriers and safety training, but IoT technology will automatically identify danger
and sound alarms.

5) **Energy:** Pre-arranged energy production and distribution will be replaced by optimal energy production and distribution based on changes in supply and demand as well as changes in the operating environment, thus saving costs and reducing CO₂ emissions.

In addition, virtual factories, which are currently used for training, will make product development possible in cyberspace, reducing time and expenses.

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### Key smart factory projects of POSCO

The following are some smart factory projects for the Gwangyang steel factory: analyzing causes of defects using a digital genome map, addressing issues using big data, and utilization of AI and virtual factories.

1. **Material to final product defect tracking**

   During the course of processing plates, the steel frequently changes length and shape. Therefore, quality control engineers need much time and effort to collect and analyze hundreds of thousands of data sets generated during each process in order to identify the causes of defects. It is also difficult to find the precise cause. To solve this problem, POSCO has devised a way to collect real-time macro and micro data on operations, quality control, and maintenance corresponding to each unit of length and width of products, and connecting the data from each process phase, thus more than halving the time needed for engineers to analyze data. For example, if the surface defect detector (SDD) detects any cracks in a plate, operation, quality control, and maintenance data from the previous processes are analyzed in 100mm increments of the product in each phase, tracing back from plates to mother plate and slab, as shown in Figure 2. Doing this allows engineers to determine the precise cause of a defect, leaving more time for product improvement.

2. **Minimizing unnecessary scarfing in the continuous casting process**

   The scarfing process, which removes surface defects from slabs, is the highest bottleneck process. WP products are all scarfed, as they demand high quality. However, in the case of general steel products, only slab samples are examined, and if there is a defect, the whole lot of slabs with the defect is scarfed. This means that normal slabs are unnecessarily scarfed. The recent increase in production of WP products has overloaded the scarfing process, necessitating the expansion of production capacity.

   The Gwangyang smart factory analyzes struc-
tured and unstructured data from connected processes and automatically detects surface defects on individual slabs. This allows the scarfing process to be conducted only when necessary, thus reducing the load and using the current scarfing capacity to produce more WP products. Finding the root cause of quality defects improves the upstream processes (steel-making and continuous casting), and guides the downstream processes (rolling and shearing) to optimal operation, profoundly reducing defects in the final product. This is a prime example of problem solving using data and software without expanding capacity.

3. New product development simulation in cyberspace
The steel-making process entails large-scale facility investments, so it is difficult to have separate processes to test new products. Moreover, owing to the innate characteristics of steel production, it is also difficult to create a new product and test functions through design and simulation software, as is done with home appliances such as refrigerators and washing machines. To address these challenges, on-going research into virtual factories is required to enable new product development and simulation in a cyber environment. In a virtual factory, facilities built by 3D technology are integrated with advanced control algorithms and operational technologies, based on steel production knowhow, and used for training and advanced commissioning. In the near future, virtual factories will be able to conduct pilot production, which would otherwise require tremendous expense.

The Fourth Industrial Revolution has already started and is expected to have a great impact on the survival and development of companies. Taking this as an opportunity for growth, companies should strive to advance manufacturing and create new value for humanity.

Implications for the Asian Steel Industry
Not resting on its exemplary success in manufacturing, POSCO will strive for relentless, long-
term innovation in order to become a role model for the advancement of global manufacturing. Many Asian steelmakers are also actively developing advanced technologies to respond to the massive paradigm shift caused by the Fourth Industrial Revolution. In cooperation with industry, academia and research, the leading steel mills will continue to develop technologies such as AI and virtual factories and apply them to production sites. They will strengthen integration along value chains by connecting clients and suppliers through smart factories.
China’s manufacturing industry has maintained high growth over the past thirty years, and China became the world’s largest manufacturing nation in 2010. In many industries, including steel, half of global production comes from China. China became the “factory of the world.” Grappling with issues like rising labor costs, export slowdown, and overcapacity, however, the growth of China’s manufacturing slowed significantly in the last several years. In some industries struggling with overcapacity, including steel and shipbuilding, operation rate is just 60-70% and profitability has fallen. Some companies have massive profit losses. Under these circumstances, the Chinese government and companies have taken great pains to tackle the difficult situation, turning their eyes to the Fourth Industrial Revolution and the rise of smart factories in advanced manufacturing countries.

“Made in China 2025” and “Internet Plus”
To prepare for the Fourth Industrial Revolution, represented by “Industry 4.0” in Germany and “Industrial Internet” in the USA, the Chinese government released the “Made in China 2025” policy in May 2015 and the “Internet Plus” action plan two months later. Chinese companies have a growing interest in Industry 4.0, smart factories, and cyber-physical systems (CPS) and are following government policy directions.

The concept of “Internet Plus” was first proposed by Premier Li Keqiang in his government work report at the meeting of the National People’s Congress of the People’s Republic of China on March 5, 2015. According to the Xinhua News, the official press agency of China, the action plan will integrate mobile Internet, cloud computing, big data and the Internet of Things (IoT) with modern manufacturing to encourage the healthy development of e-commerce, industrial networks, and Internet finance, and to help Internet companies increase their international presence. This means that China hopes to make the most of the world’s largest population of Internet and mobile phone users.
The “Made in China 2025” plan has five basic directions: ▲ innovation-driven, ▲ emphasizing quality over quantity, ▲ green development, ▲ optimizing the structure of Chinese industry, and ▲ talent-oriented. Of these, the Chinese government is putting the utmost emphasis on innovation. The plan also suggests four guiding principles: ▲ market-oriented and government-guided, ▲ based on the present and having a long-term perspective, ▲ comprehensively pressing forward and making breakthroughs in key areas, and ▲ independent development and win-win cooperation. In addition, nine objectives have been identified, including upgrading the manufacturing sector to boost manufacturing innovation, and deep integration of informatization and industrialization.

The plan also sets forth implementation guidelines for five key projects: ▲ construction of a national manufacturing innovation center, ▲ smart manufacturing, ▲ strengthening industrial base, ▲ green manufacturing, and ▲ high-end equipment innovation. China has selected ten priority sectors, including new advanced information technology, high-end computer numeric control (CNC) machine tools, and robotics.

To ensure the realization of the plan, the Chinese government has announced eight actions for policy improvement: ① deepening reform of systems and mechanisms, ② creating a fair and competitive market environment, ③ enhancing financial support policies, ④ expanding the level of support in fiscal and taxation policy, ⑤ developing a multi-tier personnel training system, ⑥ improving policies for small and medium-sized enterprises, ⑦ further opening China’s manufacturing sector to foreign investment, and ⑧ strengthening the mechanisms for organization and implementation.

It is important to note that the “Made in

Table 1. Goals of China’s “Internet Plus” Action Plan

<table>
<thead>
<tr>
<th>Areas</th>
<th>Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic growth</td>
<td>- Upgrade manufacturing, agricultural, energy, and eco-friendly industries, and increase labor productivity through the Internet</td>
</tr>
<tr>
<td></td>
<td>- E-commerce and internet finance training</td>
</tr>
<tr>
<td>Social development</td>
<td>- Public-friendly application of the Internet in areas including health, medical, education, and transportation</td>
</tr>
<tr>
<td></td>
<td>- Online and offline integration of common service and diversification of service</td>
</tr>
<tr>
<td>Construction of infrastructure</td>
<td>- Build next-generation broadband telecommunications networks</td>
</tr>
<tr>
<td></td>
<td>- Construct new infrastructure including IoT and cloud computing</td>
</tr>
<tr>
<td></td>
<td>- Promote industrialization of AI technology</td>
</tr>
<tr>
<td>Creation of environment</td>
<td>- Raise awareness of Internet convergence and innovation</td>
</tr>
<tr>
<td></td>
<td>- Prepare for related laws and regulations, standards, and legislative and credit structures</td>
</tr>
</tbody>
</table>

Source: State Council of China; Global Economic Review, Bank of Korea, August 18, 2016
China 2025” plan is the first step in a three-stage plan to make China a strong manufacturing and innovation nation. China has classified the world’s powerful manufacturing and innovation nations into three tiers: the USA comprises the first tier, Germany and Japan are in the second tier, and the UK, France, Korea, and China are in the third tier. China aims first to become a second-tier nation by 2025. The second step is to be able to compete with developed manufacturing powers like Germany and Japan to take the lead in the second tier, by 2035. The third step is for China to join the ranks of the world’s top leading manufacturing powers, and be on par with the USA, by 2049—the 100th anniversary of the founding of the People’s Republic of China.

Through the “Internet Plus” action plan and “Made in China 2025” policy, China is trying to climb on the bandwagon of the Fourth Industrial Revolution, and even take the lead in this global phenomenon. Taking the new industrial revolution as an opportunity, China aims to leverage its influence in neighboring countries under the “One Belt, One Road” initiative unveiled in March 2015. In other words, the “Internet Plus” action plan and “Made in China 2025” policy encompass not only the concepts behind Germany’s “Industry 4.0” and US-led “Industrial Internet,” but also China’s medium- to long-

Figure 1. Three-stage Plan for Becoming a Strong Manufacturing and Innovation Nation

<table>
<thead>
<tr>
<th>Made in China 2025 (’15 ~ ’25)</th>
<th>Developed manufacturing power (’26 ~ ’35)</th>
<th>Innovative leading manufacturer (’36 ~ ’49)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Increase core competitiveness and labor productivity through integration of manufacturing and the Internet</td>
<td>• Compete with developed manufacturing nations</td>
<td>• Secure advanced competitiveness in key industries</td>
</tr>
<tr>
<td>• Enter the world’s second-tier manufacturing group (Germany, Japan, and China)</td>
<td>• Lead global markets in advantageous industries</td>
<td>• Lead the global market innovatively</td>
</tr>
<tr>
<td>• 5 basic directions and 9 tasks*</td>
<td>• Take the lead in the second-tier manufacturing group (China, Germany, and Japan)</td>
<td>• Enter the first-tier manufacturing group</td>
</tr>
<tr>
<td>• 5 key projects and 10 priority sectors*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 4 guiding principles and strategic support in 8 areas</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*9 Tasks:
1. Upgrading the manufacturing sector to boost the ability in manufacturing innovation,
2. Integrating informatization and industrialization,
3. Strengthening the industrial base,
4. Fostering Chinese brands,
5. Enforcing green manufacturing,
6. Promoting breakthroughs in 10 priority sectors,
7. Advancing restructuring of the manufacturing sector,
8. Promoting service-oriented manufacturing and manufacturing-related service industries,
9. Internationalizing manufacturing

*10 Priority Sectors:
1. New advanced information technology,
2. High-end numeric control machine tools and robotics,
3. Aerospace equipment,
4. Ocean engineering and high-tech ships,
5. Modern rail transport equipment,
6. Energy saving and new energy vehicles,
7. Power equipment,
8. Agricultural machinery,
9. New materials, and
10. Biopharma and high performance medical devices
China has an undeniable advantage in its manufacturing base. China has the world’s largest manufacturing base and is dubbed the “factory of the world.” The strength of the existing manufacturing base is important in the adoption and spread of smart factories.

term strategies of boosting manufacturing and innovation capabilities, achieving industrial sophistication, and increasing China’s influence overseas.

As the “factory of the world,” China has been solidifying its position in manufacturing. If it succeeds in integrating and utilizing the Internet and artificial intelligence (AI) technology in manufacturing, China will find new opportunities. In particular, smart factories, a key concept of Industry 4.0, could alter the future of China’s troubled manufacturing industry.

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**Potential and limitations of China’s smart factories**

According to MarketsandMarkets and the Korea Embedded Software and System Industry Association (KESSIA), the global smart factory market is expected to grow at a CAGR of 5.4%, from USD 41.3 billion in 2014 to USD 56.6 billion in 2020. By technology, telecommunications has the highest projected growth rate, 8.1%. By country, China had the largest share of the smart factory market in 2013 (18.8%), followed by Germany (15.1%), the USA (12.5%), Japan (13.3%), and

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**Table 2. Global Smart Factory Market Forecast by Technology**

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensors, controller</td>
<td>45</td>
<td>47</td>
<td>49</td>
<td>51</td>
<td>56</td>
<td>61</td>
<td>4.5%</td>
</tr>
<tr>
<td>Telecommunications</td>
<td>32</td>
<td>36</td>
<td>39</td>
<td>42</td>
<td>49</td>
<td>57</td>
<td>8.1%</td>
</tr>
<tr>
<td>Industrial robots</td>
<td>278</td>
<td>296</td>
<td>313</td>
<td>331</td>
<td>336</td>
<td>401</td>
<td>5.2%</td>
</tr>
<tr>
<td>Logic and distributed control</td>
<td>33</td>
<td>34</td>
<td>36</td>
<td>38</td>
<td>42</td>
<td>47</td>
<td>5.3%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>388</td>
<td>413</td>
<td>437</td>
<td>462</td>
<td>513</td>
<td>566</td>
<td>5.4%</td>
</tr>
</tbody>
</table>

Source: MarketsandMarkets, KESSIA
Smart factories involve various technologies: control systems, such as sensors, programmable logic controllers (PLC), and distributed control systems (DCS), which monitor and conduct manufacturing processes; and manufacturing applications, including manufacturing execution systems (MES), enterprise resource planning (ERP), product lifecycle management (PLM), and supply chain management (SCM). Sensors, controllers, and manufacturing applications are interconnected through big data, IoT, and cloud platforms. The key aspect of a smart factory is the construction of CPS, which integrate the physical domain of manufacturing facilities and the digital domain, including controlling and communication.

In short, a smart factory is the integration of existing manufacturing technologies and new ICT. Therefore, the strength of the existing manufacturing base is important in the adoption and spread of smart factories. China has an undeniable advantage in its manufacturing base. China has the world’s largest manufacturing base and is dubbed the “factory of the world.” Therefore, China has a bright future in the compilation of big data, which is important in realizing smart factories.

The Chinese government’s massive support makes the prospect of smart factories even brighter. It plans to designate two to three companies in each industry to support the construction of smart factories. Government support includes subsidies, tax exemptions, and technology development. The designated pilot companies will receive support that will put them out ahead of their global competitors.

Using its vast market as a bargaining chip in summit diplomacy, China induces cooperation from advanced global firms. As a result, China can elicit technological support for smart factories from advanced countries. In March 2014, Chinese President Xi Jingping held talks with German Chancellor Angela Merkel in Berlin, and they agreed to upgrade bilateral relations to an all-round strategic partnership. After several subsequent rounds of meetings, they agreed to forge ahead with the advancement of the Fourth Industrial Revolution. During his state visit to Germany in November 2014, Chinese Premier Li Keqiang announced the “Outlines for China-Germany Cooperation: Joint Innovation,” and agreed to promote China-Germany cooperation in Industry 4.0.

Chinese companies are also seeking global cooperation in Industry 4.0. In June 2016, in the presence of Chinese Premier Li Keqiang and German Chancellor Merkel, the presidents of Baosteel Group Corporation and Siemens AG signed “the strategic agreement of intelligent manufacturing (Industry 4.0).” Furthermore, Siemens employed the system of Amberg’s smart factory in Siemens Electronic Works Chengdu (SEWC), which began operation in September 2013. SEWC is the first digital firm that Siemens established outside Germany and the USA.

Considering the experience and technology of Chinese manufacturing, however, there is a long way to go before smart factories gain ground in...
Due to the technology gap and varying levels of advancement among the manufacturing bases of steelmakers, the Chinese steel industry needs to employ selection and concentration, and phased implementation of smart factories.

China. First of all, Chinese manufacturers have different degrees of advancement when it comes to manufacturing bases. The level of most Chinese firms falls between Industry 2.0 and Industry 3.0. The prevailing opinion is that it is more urgent to upgrade to Industry 3.0 than to adopt smart factories.

Moreover, China still lags behind advanced countries in terms of the technological ability to build and analyze big data and CPS. Most importantly, China lacks the experts necessary to introduce and realize smart factories. For these reasons, the Chinese government is emphasizing innovation and the nurturing of talent.

Phased implementation of China’s smart factory
Considering this reality, Chinese experts have suggested the concept of smart factory 1.0 and insisted on phased implementation. Wang Jian, Secretary General of the China Science & Technology Automation Alliance presented “smart factory 1-2-3” as a development model for smart factories. The “1” means to raise capability to accumulate and analyze big data, the key element of smart factories. The “2” is to ① form an alliance between smart equipment manufacturers and consumer goods manufacturers and ② integrate digital manufacturing and smart manufacturing. The “3” refers to a threefold integration—horizontal, vertical, and lifecycle integration, ultimately building CPS through the integration of the physical domain and the digital domain. Based on these steps, Wang proposes that China announce “smart factory 1.0” for the time being, spend the next five years building the basis for smart factories, and implement “smart factory 2.0 and 3.0” after 2020.

A comparison with advanced countries, including the USA and Germany, illuminates China’s need for phased implementation of smart factories. In the USA, enterprises formed partnerships with the government to build the basis for smart factories, focusing on the development of new ICT, including big data, data analysis, virtual reality systems, and IoT. In Germany, enter-
Asian Steel Watch

prises with strong manufacturing bases led the introduction of smart factories in the early phase, but soon faced limitations. Motived by the cooperation between enterprises and the government in the USA, Germany now seeks private-public implementation of smart factories. On the other hand, China’s policy direction dictates that companies implement government initiatives for smart factories. With the different levels of advancement among companies, the Chinese government has adopted the selection and concentration strategy, concentrating support on leading companies in each industry.

Thanks to the Chinese government’s efforts, leading companies in some industries seem to be close to the realization of smart factories. If these companies see tangible results, the spread of smart factories will be expedited and leap several stages. According to Chinese media, China’s largest home appliance company, Haier, is the first home appliance company to have a smart factory. In 2015, Haier established four internet-based smart factories, including the refrigerator factory at Shenyang in Liaoning province. At this plant, the 100-meter production line was replaced by four production lines of 18 meters each. Hundreds of parts are automatically sorted and grouped according to pre-set data. The factory enables mass production of various products to meet customer needs in a timely manner. As a result, the factory has reduced its workforce by 57%, increased production capacity by 80%, and cut time-to-market and delivery lead time by 47%. Also in the automotive sector such leading automakers as Changchun, Yiqi, and Shanghai Volkswagen are gearing up to introduce smart factories.

The response of Chinese steelmakers and upcoming challenges for the global steel industry

The spread of smart factories brings new wind to the Chinese steel industry. In a mire of over-capacity and strict environmental regulations, steelmakers are losing profitability, and are threatened by drastic restructuring. Under these
circumstances, smart factories could bring new momentum to the steel industry. Some leading Chinese steelmakers have already automated production facilities, because these are the continuous process. They will be able to realize smart factories simply by integrating new ICT with existing facilities to build CPS. This is why some steelmakers are actively trying to adopt smart factories.

Shanghai Meishan Iron and Steel (Meigang), a subsidiary of Baosteel Group, has already included smart manufacturing in its medium- to long-term strategy, and is implementing this strategy in phases. Baosteel is poised to move beyond smart factories to lead smart manufacturing in the steel industry. Baosteel’s ambitious e-commerce platform, Ouyeel, is not just for simple online transactions, but a platform for collecting and analyzing big data on customers and markets. In this sense, the steel e-commerce boom that began in China last year linked to Industry 4.0. Shanxi-based private steelmaker Shanxi Jianbang Group has adopted smart factories and is implementing the “5+1+1” online model. The “5” refers to smart inventory, smart logistics, smart procurement, smart sales, and smart recycling, and the two “1”s represent smart manufacturing and smart finance.

Due to the technology gap and varying levels of advancement among the manufacturing bases of steelmakers, the Chinese steel industry needs to employ selection and concentration, and phased implementation of smart factories. The level of development with regard to smart factories depends on the relative size and competitiveness of the company. Small and medium-sized steelmakers will focus on the early stages of automation and management of manufacturing records and defect logs. Steelmakers of middle standing will concentrate on facility management using sensors, and collection and management of real-time production information. Large steelmakers will pursue real-time system connection and real-time automation control of their smart factories using PLC. In addition, some mega-sized steelmakers will aim for multifunctional intelligence, wired and wireless communication with AI, and autonomous production of facilities and systems. In particular, leading steelmakers with well-established manufacturing bases will increase investments in smart factory-related technologies, including big data, CPS, smart sensors, IoT, cloud computing, and gear up to develop these technologies.

In conclusion, the phased introduction of Industry 4.0 and smart factories will revitalize Chinese manufacturing and create an opportunity for China to shift from the “factory of the world” to the “smart factory of the world.”

However, it would take much time and energy to fully realize smart factories in China’s manufacturing and steel industries. Despite mounting difficulties, a promising path lies ahead for China. Just as the explosive growth of China’s steel industry has shocked the world in the early 21st century, the world might be shocked again by China, if it successfully adopts Industry 4.0 and smart factories in the future. Now the global steel industry should pay close attention to the rise of Industry 4.0 and smart factories in China.
Steel e-commerce is gaining ground in China. One might overlook this as part of the global spread of e-commerce. However, much attention is being paid to the spread of China’s steel e-commerce that could be a renowned trading platform in Asia though advanced countries have already experienced the rise and fall of steel e-commerce.

In the late 1990s when “dot-com” fever swept the world, the first steel e-commerce boom began. Steelmakers, steel distributors, and venture capitalists in major steel-producing countries, including the USA, Japan, European countries, and Korea, led the expansion of e-commerce.

However, the boom was short-lived for several reasons. Profit models were inadequate given the massive investments made, and the characteristics of steel trade were not fully reflected in online trade. Moreover, entry barriers were raised for traditional offline distributors (See Table 1).

### Background and sustainability of China’s steel e-commerce boom

Ten years later, a second steel e-commerce boom began in China. The number of steel e-commerce platforms increased eight-fold and the transaction amount increased ten-fold from 2012 to 2015 (See Figure 1).

The rapid growth of China’s steel e-commerce was caused by three factors that collectively intensified competition in online platforms: the changing landscape of the steel trading market due to a slump in China’s steel industry; China’s “Internet Plus” and other related policies; and an online fever across the industry. The first factor was the declining number of Chinese steel distributors giving rise to new business opportunities. The number of Chinese steel distributors reached 200,000 in 2012, but fell by half to 100,000 in 2014. This is attributed to management difficulties caused by sagging steel prices following a decline in steel production and consumption in China’s steel industry.
China, and financial difficulties due to strengthened lending regulations. The second factor was the effects of the Chinese government’s policies modeled after Industry 4.0 of Germany. In 2015, the Chinese government unveiled the “Made in China 2025” plan to increase the competitiveness of manufacturing, and began implementing the “Internet Plus” action plan, which links the Internet with almost all industries. The Chinese government aims to handle 20% of steel transactions online by 2025, which is leading to active participation by major state-owned steel companies. Lastly, with the widespread success of online platforms such as Alibaba, massive amounts of human and financial resources began pouring into China’s steel e-commerce.

The question is whether China’s steel e-commerce will deflate and be reduced to a limited online sales system for non-ordered products, as happened in other advanced countries. China’s steel trading market has distinctive features that are different from those of other major steel-producing countries. Therefore the boom will not be a passing fad like the dot-com bubble. Because general long and flat steel products are the main products traded on e-commerce platforms, the future of China’s e-commerce depends on the characteristics of the steel distribution markets where these products are dealt with.

Consider Korea, China, and Japan. Japanese
so to strengthen their footholds, and venture capital and information consulting firms branch into e-commerce to take new business opportunities. These are the four main market players in competition. In terms of expertise in steel, steelmakers have an advantage because they produce steel products and hold processing and logistics networks. Next are distributors, which have processing and logistics capabilities and market demand base. Venture capital and information consulting firms are regarded as having less ex-

steelmakers have a large influence on the steel distribution market, and market competition is relatively low. Chinese steelmakers have less influence on the steel distribution market because steelmakers and distributors have grown independently in the rapidly rising steel industry, and competition is fierce amidst worsening oversupply. In Korea, steelmakers have moderate influence because they have utilized regional distributors during the growth period of the steel industry, and the level of competition is between that in China and Japan (See Table 2).

Facing diminished profitability, Chinese steelmakers, which used to have little influence on distribution, have turned their eyes to e-commerce. In addition, various market players, including distributors, venture capital firms, and information consulting firms, are making inroads into steel e-commerce for various different purposes. For these reasons, the steel e-commerce boom will not end soon in China. Steelmakers enter steel e-commerce to increase their clout in the distribution market, while distributors do

### Table 2. Characteristics of Steel Trade Market in Northeast Asia

<table>
<thead>
<tr>
<th>Country</th>
<th>Influence of steelmakers</th>
<th>Level of competition</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Korea</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Japan</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

- **China**: Steelmakers and distributors have grown independently in the rapidly rising steel industry. Fierce competition amid oversupply → 50% (3.5 Mt) of steel demand traded by distributors.
- **Korea**: Steelmakers have used regional distributors through contracts. Unstable competition structure due to surging inflows of imports → 30% (18.5 Mt) of steel demand traded by distributors.
- **Japan**: Steelmakers do business with distribution companies involving domestic and overseas sales. Stable competition structure → 25% (17 Mt) of steel demand traded by distributors.

Source: POSCO Research Institute, 2015

![Figure 2. Competition Landscape of Steel E-Commerce](source_url)
Depending on the level of implementation of “Made in China 2025” and “Internet Plus,” China’s version of Industry 4.0, more sophisticated models could appear, encompassing order sales.

### Table 3. China’s Top Five Steel E-Commerce Platforms (2015)

<table>
<thead>
<tr>
<th>Platforms</th>
<th>Year of establishment</th>
<th>Established by</th>
<th>Trade volume (Mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.zhaogang.com">www.zhaogang.com</a></td>
<td>2012</td>
<td>Venture capital firm</td>
<td>32</td>
</tr>
<tr>
<td><a href="http://www.banksteel.com">www.banksteel.com</a></td>
<td>2008</td>
<td>Information consulting firm</td>
<td>28</td>
</tr>
<tr>
<td><a href="http://www.opsteel.cn">www.opsteel.cn</a></td>
<td>2005</td>
<td>Trader</td>
<td>NA</td>
</tr>
<tr>
<td><a href="http://xinyilian.com">http://xinyilian.com</a></td>
<td>2012</td>
<td>Trader</td>
<td>13</td>
</tr>
<tr>
<td><a href="http://www.ouyeel.cn">www.ouyeel.cn</a></td>
<td>2015</td>
<td>Steelmaker</td>
<td>10</td>
</tr>
</tbody>
</table>

Source: Compiled by Chinese media reports, It is Time to Prepare for Steel E-Commerce Fever in China, Kim Hong-Sik, Steel Daily, 2016

According to experts in steel, however, they have an advantage in terms of expertise in e-commerce platforms, while steelmakers and distributors have a relative disadvantage. Notably, venture capital firms with strong financing capabilities have an advantage, as they can make intensive investments from the beginning (See Figure 2).

Five steel e-commerce firms account for more than 90% of total steel trade volume through e-commerce in China: venture capital-funded Zhaogang, which has the largest market share; Banksteel, a subsidiary of information consulting firm Mysteel; Opsteel and Min-Metal subsidiary Xinyilian, which are sponsored by distributors; and Ouyeel, which is a subsidiary of steelmaker Baosteel (See Table 3).

### Steel e-commerce business will be led by two or three major firms

The Chinese government aims to increase total steel trade through e-commerce by about 20%, or 150-200 Mt. Considering the Chinese government’s drive, this goal is attainable. “China can standardize 400 Mt of steel materials. As 100 Mt of steel materials are currently traded online, the steel e-commerce business has high growth potential,” said Gan Yong, Vice President of the Chinese Academy of Engineering (CAE).

China’s steel e-commerce market will be led by a few competitive firms for three reasons. First, oversupply will be gradually relieved as the Chinese steel industry undergoes strong restructuring, by phase, over the next five
There are various forecasts on the reorganization of China’s steel e-commerce industry. The Chinese government, which currently supports around 30 platforms, predicts that 5-10 platforms will survive over the next five years. Zhaogang, BankSteel, and Ouyeel will become the first-tier group, leading the reorganization of the steel e-commerce market. The second-tier group, mainly led by large distributors, including Opsteel, will be the first target to be merged, and the third-tier group, consisting of the remaining smaller companies, will disappear or be incorporated into large platforms. Another forecast predicts that the steel e-commerce market will be led by two big powers, considering the characteristics of e-commerce business. Just like the e-commerce business for consumer goods, which is led by two big companies, Taobao and Jingdong, there is a possibility that the steel e-commerce market will be led by two major parties: the steel-makers and an alliance of third-party platforms.

China’s steel e-commerce platforms are grappling with profitability, just as businesses in advanced steel-producing countries did in the past. Except for Ouyeel, which posted a slight surplus in 2015, Chinese steel e-commerce firms are running deficits. Their model is not to charge transaction fees, but to find cash cows in advertising, logistics, finance, and information. To take the lead in the market, they also seek quantitative growth and plan initial public offerings (IPOs) in one or two years. China’s steel e-commerce platforms generally handle ordered and non-ordered products of flat and long steels; and these products are mostly general products. They plan to expand the scope of business from general steel to high-quality steel, and from inventory sales to order sales, however, this will be difficult given the size of the market, business opportunities, and profitability.

Considering the size of the market, business opportunities, and profitability, China’s steel e-commerce will not be just a fad. This will be especially true if Chinese-style Industry 4.0 is reflected in the steel industry.
the characteristics of the steel trade. Therefore, they will likely end up being channels for inventory sales of general steel products. Major firms have already tried to move independently toward order sales, but they have faced many difficulties, and postponed this goal. However, depending on the level of implementation of “Made in China 2025” and “Internet Plus,” China’s version of Industry 4.0, more sophisticated steel e-commerce models could appear, encompassing order sales.

China’s steel e-commerce firms pioneering overseas markets
China’s major steel e-commerce firms are broadening their sales channels. In terms of regional expansion, results vary by company. Zhaogang entered Korea and Vietnam, respectively in 2014 and 2016. It is also building subsidiaries in Thailand and Dubai. There are mixed views on Zhaogang’s entry into the Korean market. Based on interviews, Zhaogang entered Korea because Korea is China’s largest steel export market, with annual imports of 13 Mt, and steel prices are higher in Korea than in China. As general long and flat products are typically traded by small and medium-sized steel traders in Korea, Zhaogang believed it would have a competitive advantage over Korean steel traders if it strengthened its functions of storage, logistics, and processing, by phase, in Korea. Ouyeel entered the Southeast Asian market by establishing a subsidiary in Sin-

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Types of steel e-commerce
B2B e-commerce is divided into four types depending on the complexity of transactions and degree of product involvement: e-procurement, e-distribution, e-partnership, and e-marketplace. China’s steel e-commerce encompasses all four types, but focuses especially on e-marketplace. In this article, e-commerce mainly refers to e-marketplace. “E-procurement,” which has low product involvement and high complexity of transactions, deals with the purchase of maintenance, repair, operation (MRO) materials. “E-distribution,” which entails transactions with sales channels, has low complexity but high involvement, while “e-partnership,” which supports sales of tailored products, has high complexity and high involvement. E-distribution and e-partnership, which have high product involvement, are characterized by the use of online platforms to increase offline trade. Finally, “e-marketplace” has high complexity and low involvement.
In the short-term, e-commerce will take root as a distribution channel for general steel products in China. In the medium- to long-term, it will become the main sales channel for 100 million tonnes of Chinese steel exports.
Impact of expanding steel e-commerce in China

As Chinese steel e-commerce firms branch into overseas markets, each step will have corresponding impacts. In Korea, which is the largest importer of Chinese steel products, Chinese platforms will accelerate their entry into the Korean market by building offline channels first and replace local steel importers. In order to prepare for this situation, Korean steel e-commerce platforms led by steel-makers and distributors are expected to strengthen the role and function of existing platforms and create new platforms. This will put pressure on the restructuring of the steel distribution market.

In the case of emerging markets, including Southeast Asia, steel e-commerce will not spread as fast as it did in China. Chinese platforms seek gradual expansion, such as building offline channels first and then transferring business from offline to online. By doing so, their influence will become stronger in emerging markets. There will be various forms of competition and collaboration with large steel trading companies and small and medium-sized steel importers doing business in emerging markets.

Considering the size of the market, business opportunities, and profitability, China’s steel e-commerce will not be just a fad. This will be especially true if Chinese-style Industry 4.0 is reflected in the steel industry. In the short-term, e-commerce will take root as a distribution channel for general steel products in China. In the medium- to long-term, it will become the main sales channel for 100 million tonnes of Chinese steel exports. In overseas markets, however, Chinese steel e-commerce firms will assume the functions of offline steel traders, rather than seeking rapid online expansion by building a spate of steel e-commerce platforms as in China. They will expand their functions incrementally, mainly in emerging markets. In this process, existing steel distribution channels, which have been operated offline, will be upgraded through integration with online channels in each market. As a result, Chinese steel e-commerce platforms will be able to increase their clout in overseas steel distribution channels.
Ask the Guru: Roads Ahead for the Steel Industry

Dr. Edwin Basson
Director General, World Steel Association (worldsteel)

After a few years in the banking industry, Edwin Basson joined the steel industry in 1994 as Chief Economist at Iscor Ltd. in South Africa. In 1996, he became Business Unit Manager for coated steel products and flat steel products. He later headed Strategic Initiatives at the company. Edwin was transferred to Europe when Iscor became a part of Mittal Steel (now ArcelorMittal) in 2004 as a General Manager responsible for Marketing Strategy and was part of the Merger & Acquisition team in Mittal steel. From 2006 until he joined worldsteel, he was Vice President, Commercial Coordination, Marketing and Trade Policy at ArcelorMittal. Edwin joined worldsteel in August 2011 as Director General. Edwin received his PhD in economics from Pretoria University. He taught economics at the same university from 1984 to 1990.
**Q:** What is the major role and function of worldsteel? Please describe the core business of worldsteel in brief.

**A:** worldsteel was established 50 years ago in Brussels as an association to represent the interest of steel producers. For the first 40 years it was known as the International Iron and Steel Institute (IISI), but in the last decade the membership has expanded to include steelmakers from all important steel-making countries around the world. Consequently the name changed to the World Steel Association—or worldsteel—to reflect the changed membership.

The main focus is to act as a global leader on issues of importance to the steel industry. At the most basic level, worldsteel gathers data about the performance of the steel industry. These statistics support a range of benchmarking evaluations about important topics in the industry. These could be concerned with safety performance, production efficiency, the environmental impact of steel production, and a host of other benchmarking topics that the industry could use to improve efficiency. worldsteel also initiates pioneering projects to improve sustainability in the industry such as lightweight autobody steels, life cycle assessments (LCA), and other megatrend topics. Lastly, the association ensures that the industry has an aligned message about the importance of steel to modern society.

The steel industry enables the survival of a modern sustainable society. Without steel, it is not possible to meet the demands for housing, transportation, efficient energy creation, and all the other activities that modern society requires. The task of worldsteel ensures that steel as a product and steel as an industry maintain its key role to sustain modern society.

The future of our industry will be challenging. At least three areas of impact need to be addressed. In the short term, the industry is faced with supply imbalances in many parts of the world that contribute to challenging market conditions for our products. The global economy is unstable, in many cases still trying to absorb the aftereffects of the global financial crises of 2008-09. At the same time, global economic activity is gradually shifting to new geographical locations, following population growth and economic development trends. Consequently, the steel industry has to adjust with these geo-social trends. Secondly, growing environmental restrictions will apply growing pressure on the steel industry to effectively address the question

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**It is clear that steel use in China has reached a point where future increases in steel use are difficult to foresee. In that sense the Chinese economy may be in the vicinity of a steel use peak for the near future.**
of carbon emissions. The solution will most likely be combinations of new production techniques requiring large amounts of R&D funding in years to come, and different approaches to attach a cost to carbon emissions. Lastly, steel as a product has become much stronger and lighter in recent years in almost every application. Accordingly, today, on a global basis we require only 75% of the steel to create one unit of GDP that the world required in 1975. This process will continue and the steel industry must react by promoting our product, addressing productive capacity accordingly.

Q: This year global steel demand is expected to remain sluggish. What do you think is the cause of the slowdown and when will the global steel industry be able to recover? In particular, how do you see the global steel industry in 2017?

A: Like any other industry that is highly integrated with the rest of the economy, the steel industry is affected by structural and cyclical fluctuations of the global economy. Structural forces are longer term in nature and have lasting impacts, while cyclical forces are more volatile and changeable over the short term. The confluence of significant economic adjustment in many economies—some driven more by structural forces and others more by cyclical forces—impacts on steel demand in the present period.

The most important element in this regard is the structural changes that are happening in China these days. The slowdown in Chinese growth is in itself the result of structural changes in the Chinese economy. The shift from an investment-driven economy, the significant increase in urbanization and average income levels coupled with the high levels of existing infrastructure and urban property in most of China suggest that China is going through a structural adjustment in the level

<table>
<thead>
<tr>
<th>Table 1. worldsteel Short-term Demand Outlook</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>Amount (Mt)</td>
</tr>
<tr>
<td>World</td>
</tr>
<tr>
<td>European Union (28)</td>
</tr>
<tr>
<td>Other Europe</td>
</tr>
<tr>
<td>CIS</td>
</tr>
<tr>
<td>NAFTA</td>
</tr>
<tr>
<td>Central &amp; South America</td>
</tr>
<tr>
<td>Africa</td>
</tr>
<tr>
<td>Middle East</td>
</tr>
<tr>
<td>Asia &amp; Oceania</td>
</tr>
<tr>
<td>China</td>
</tr>
<tr>
<td>Developed Economies</td>
</tr>
<tr>
<td>Developing Asia ex. China</td>
</tr>
</tbody>
</table>

Source: worldsteel
of future growth in the Chinese economy. While growth will remain positive, it will be at significantly lower levels than in the past with much less contribution of investment to growth.

These structural events intermingle with the cyclical patterns of persisting weak growth in the rest of the world; growing levels of government debt and declining appetite for risk by the corporate sector contribute to weak global economic growth.

Weak economic growth results in weak steel use patterns. While Chinese steel demand declined, no other economic region grew strongly enough to neutralize the deceleration of China. In fact, with steel being an input to so many industrial sectors and sensitive to investment, steel demand tends to show greater fluctuations than GDP. This explains why steel demand growth has been so weak in recent years.

The work of the worldsteel Economics Committee suggests that 2016 will be the turning point and most regions will show improvement in 2017, but growth momentum will continue to be weak, reflecting continued contraction in China and weakness in other parts of the world due to the factors mentioned earlier (See Table 1).

In this regard, the continuing decline in the steel use intensity of GDP (steel use per unit of GDP) is an important trend to watch. As is clear from Figure 1 this process has been ongoing since 1975 when the process of industrialization of most developed economies came to an end and the energy saving drive affected steel use patterns. Since the early 2000s, strong growth in China has lifted the steel use intensity of GDP somewhat, but it is clear that the intensity of steel use started to decline in tandem with the deceleration of steel use in China since 2014 (See Figure 1).

Q: Steel demand in China, the world’s largest steel powerhouse, continues to decline.
INTERVIEW

most difficult is probably the rebalancing between investment and consumption in the economy. While the Chinese economy was until now predominantly an investment-led economy, it is clearly now in the process of rebalancing in favour of a demand-led system. The changeover is difficult, but the Chinese economic system still has much growth potential to be realized.

Steel use follows economic growth patterns closely, and the experiences of the developed economies suggest that steel use grows fast—actually faster than the economy itself at an early stage of economic take-off—but then reaches a peak at or close to the upper inflection point on the S-curve, before a long term decline in steel use takes place. This happens at a per capita income level of around USD 12,000-15,000 (purchasing power parity terms). Following this reasoning, one could argue that the Chinese economy has reached a point of peak steel use, and that steel use in China should be expected to

Although China maintains its GDP growth rate at over 6%, steel demand is on the decline. Why do you think this is? Do you think China’s steel demand has already passed its peak? What is the long-term forecast for China’s steel demand?

A: The decline in Chinese economic growth is a logical economic phenomenon. All previous experiences of economic development indicate an “S-curve” character, consisting of a period of preparatory, but slow growth, followed by a period of sustained rapid growth. At some point, as the economy begins to approach maturity, an upper inflection point in growth is reached, where growth generally remains positive, but at a much slower rate than before. Available evidence suggests that the recent slowdown in Chinese growth is the result of China reaching the upper inflection point in the S-curve. Amongst the many challenges facing the Chinese economy, the largest and
decline in the future. China has reached peak steel at a rather earlier stage of economic development compared with the experiences of developed economies as it has accomplished a very condensed development in a relatively short time period.

It should be noted that recent studies by the worldsteel economics team highlight a number of unique cases where, after the first peak, steel use recovered to the same or even higher levels of use. Available evidence suggests that where new development opportunities have presented themselves (such as with the unification of east and west Germany) or where the economic policy of a country targeted export-led industrial growth, steel use in the economy was able to recover to peak levels, or sometimes even beyond, as was the case in Japan (See Figure 2 and Table 2).

Against this background, it is advisable to be cautious. It is clear that steel use in China has reached a point where future increases in steel use are difficult to foresee. In that sense the Chinese economy may be in the vicinity of a steel use peak for the near future. However, the future development of Western China, the continued capability of China as a competitive manufacturing base, and the geographical location of China between a number of regions with good future growth potential could contribute to a new momentum in steel demand growth in the future. Therefore we cannot preclude the possibility that Chinese steel demand will at some future date grow again to an even higher level than the 2013 peak. It will critically depend on the success of the economic reforms China is undertaking and future demographic trends.

Q: The global steel industry is still suffering from overcapacity. How do you see China’s efforts to reduce overcapacity? As Director General of worldsteel, what kind of efforts, do you think, should be taken to

<table>
<thead>
<tr>
<th>Country</th>
<th>ACSU * per capita</th>
<th>Number of years</th>
<th>Comparison with the peak level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>542 → 400(26%)</td>
<td>13(1983)</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>826 → 550(33%)</td>
<td>10(1983)</td>
<td>10(1993)</td>
</tr>
<tr>
<td></td>
<td>802 → 561(30%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UK</td>
<td>468 → 275(41%)</td>
<td>10(1980)</td>
<td></td>
</tr>
<tr>
<td>US</td>
<td>737 → 361(49%)</td>
<td>9(1982)</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>478 → 254(47%)</td>
<td>13(1986)</td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>770 → 352(54%)</td>
<td>16(1991)</td>
<td></td>
</tr>
</tbody>
</table>

Note: *ACSU: Apparent steel use, crude steel equivalent
Source: worldsteel
We are to a large degree already living in an era where Asia leads the steel industry. Today, steel use is predominantly in Asia, which accounts for 65% of global steel use.

cut overcapacity?

A: The key question in any discussion around overcapacity is always how capacity is or should be measured. The OECD, in its effort to measure excess capacity, followed a conservative approach by measuring installed crude steel capacity against the crude steel use in the same country or region. Where capacity surpassed crude steel use, the country or region was deemed to suffer excess capacity. While many criticized this approach as too simplistic, as it does not recognize the impact of production yield losses, complex product routes, maintenance, and other factors that make it impossible to produce at full theoretical capacity, it is still the only metric that treats all regions or countries in precisely the same way. Against this metric, roughly half of global excess capacity was to be found in China—understandable as roughly half of all steel production takes place in China.

Nevertheless, reducing excess capacity is never an easy task, largely because of many hidden barriers to exit. Capacity reduction can have a significant impact on the balance sheets of operating companies, and are never popular with investors. Equally, social impacts of capacity closure are never popular with governments, labour unions and the local communities and can turn out to be very expensive in terms of redundancy costs and maintaining a stable and well trained workforce. Lastly, the workforce pays a large price in any capacity reduction, as employment opportunities are always reduced.

China has publicly announced the closure of up to 150 million tonnes over a five year period—the only economy to have publicly set a target. It remains to be seen if China will be successful, but with the determination of the current government to tackle the overcapacity problem and environmental protection, we should trust that China will be able to meet this target.

At worldsteel we know that excess capacity does have an adverse impact on the steel industry. Foremost for worldsteel is to insist that industry restructuring should take place on a "level playing field" principle and that restructuring should follow similar principles wherever it is done. To that effect, worldsteel members have agreed to the following principles on restructuring:

 Governments should promote a swift and timely restructuring of the steel industry
by advancing policies that ensure market forces play a decisive role in determining the future of the industry. Past restructuring was only successful when government support and other barriers to orderly market transformation were removed. Industrial competitiveness was maintained and improved as a result of restructuring.

Market oriented approaches should ensure survival of the fittest producers. Inefficient producers should not be subsidized to remain in operation. It is important to always maintain a level playing field among producers. Long-term sustainable producers have to meet environmental, financial and social expectations.

Barriers to exit that delay restructuring should be removed in an orderly and timely way.

Development of a long-term restructuring plan should identify and remove barriers to exit. As the steel industry remains one of the least consolidated industries, barriers which prevent efficient mergers should also be reviewed.

**Develop safety net support that mitigates the consequences of restructuring.**

Support should focus on addressing the social and environmental impact of restructuring.

**Finally, commitments to adjust the steel industry structure should be made known and tracked until finalization.**

It is natural that trade tensions will escalate during times of excess production. Fortunately, there is a very well accepted process, under the auspices of the WTO, to take care of these trade tensions, while the
Asian Steel Watch

industry aims to restructure for a more sustainable future.

**Q:** How do you see the future of the Asian steel industry? Do you think that Asia will continue to lead growth of the global steel industry? If so, why would that be? Which countries will be able to lead the future?

**A:** We are to a large degree already living in an era where Asia leads the steel industry. Today, steel use is predominantly in Asia, which accounts for 65% of global steel use, with the countries with the largest steel use per person also mostly in Asia. Asia as a region has a large population. Moreover, in many Asian countries, the economies are progressing rapidly up the economic development path. Both these factors contribute to the conditions we usually equate with growing steel use. In many Asian countries, large parts of society have not yet urbanized, income levels per person are still low, and much needs to be done to develop infrastructure to the level where economic growth could benefit from adequate levels of infrastructure (See Figure 3 and Figure 4).

Given these conditions, it is likely that Asia will remain a driving force in steel use in the foreseeable future.

Within the Asian region, future growth will likely depend more on the development of the ASEAN region, with relocation of Chinese manufacturing and growth in India strongly supporting developments in the South East Asian markets.

Countries in North Asia are already developed and therefore may not drive the steel market in Asia to the same extent as in the past. However, countries in North Asia have been important contributors as centers for manufacturing design and technology in the past, and will continue to be important in the future—playing a different but equally important role to maintain the competitiveness of the steel industry in Asia.
The interlinkages in the manufacturing capabilities between countries in the Asia region will remain important to support the growth of steel use in the region. An open trade regime, allowing countries to invest in different areas and technologies will contribute to enduring economic development in the region, and thereby maintain the leadership role for the Asian steel industry.

Other regions, such as the Middle East and Africa, may grow equally fast in terms of steel use, but the present size of these markets is not sufficient to challenge the global leadership of Asia as a region.

Q: The Fourth Industrial Revolution is heralding a new future. Innovation through IoT, big data, and smart factories will bring new changes to manufacturing. What kind of influence will the steel industry have from these changes? Do you think that steel companies will actively accommodate these changes in the near future?

A: The steel industry has a long history of technological adaptation and product innovation. Today, the industry is already extremely efficient in iron and steel making, as well as processing. Energy requirements in the steel making process are the lowest of all industrial metals, while process yields are already high and continuously increasing. Within this environment, the Fourth Industrial Revolution could continue to play an important role, but additional progress will be incremental owing to the already high level of technological achievement. Progress is always possible.

It is rather in the field of the use of steel in applications that the Fourth Industrial Revolution could play an important role. Better understanding of customer requirements and possible improvements in the manufacturing processes converting steel into consumer applications could potentially have a large impact on the steel industry. Today, after achieving high process and quality yields in the steelmaking process, it is not uncommon to discard as much as 30% of high quality steel as waste during the process of using steel to produce consumer products. The Fourth Industrial Revolution may influence the design and production of consumer goods to the extent that waste is reduced, and the lifetime of steel in use increases. Both these possibilities may reduce the steel in use per person, but provide opportunities for the steel industry to position its product as extremely durable and environmentally friendly and therefore a product to be sold and marketed in completely new ways in the future. It is therefore quite possible that the Fourth Industrial Revolution will have little direct influence on the steel industry, other than to make production control more disciplined. The indirect influence through changing the manufacturing process and product design of items requiring steel as an input may have a vastly more influential role in the steel industry, as the ways that the product is delivered to the customer could change dramatically.
Global Competitiveness Through Hybridization of FINEX and CEM Processes

Executive Summary
Since the beginning of the ironmaking process at Caucasus from about 2000 B.C, the iron and steelmaking technology has been one of the underlying foundations responsible for the modern day civilization and human advancement. It is generally accepted that the blast furnace technology was established to be a typical maxi-mill process route with the implementation of the basic oxygen steelmaking technology. However, the needs of diversification of raw materials and flexibility of process will accelerate the development of an alternative midi-mill ironmaking route by hybridization of individually optimized steelmaking technologies. The recent concept for hybridization is comprised of the FINEX and CEM technologies with particular attention for allowing a sustainable midi-mill process with high flexibility. The hybridization of the FINEX and CEM processes can provide high versatility by combining the advantages of their technological characteristics.
Sustainable steel production through the midi-mill route

As the world transitions from the financial crisis of 2008-09, the global steel industry has continued to suffer from slack demand. Excess production capacity and oversupply of imports have put high pressure on steel prices, and lowered profitability of the industry. Each country has taken specific counter measures, including higher tariffs and trade policy changes, to safeguard its own domestic market. Furthermore, heightened global environmental restrictions have limited everyday operational practices, and the steel industry has come under intense pressure to meet the challenges of recently tightened environmental standards. Thus, there has been increased interest for the global steel community to balance excess steel capacity and ensure the sustainability of the carbon steel industry through efficient and cost-effective production routes.

The blast furnace (BF)–basic oxygen furnace (BOF) route with raw materials feed from coke-making and sintering is highly energy efficient, but capital and carbon intensive. This is unfavorable in an excess capacity market and under stricter environmental regulations. In the electric arc furnace (EAF) route, high-grade quality scrap and cheap electricity are required to produce low-cost and high-quality steel due to tramp elements in raw materials. The BF route steel plant with a production capacity of more than 3 million tonnes per year (MTPY) is a maxi-mill plant and the EAF route with less than 1.5 MTPY is a mini-mill plant.

These maxi-mill and mini-mill plants have advantages and disadvantages that are at opposite ends of the carbon steel business spectrum in terms of quality and productivity. Table 1 provides some of the specific characteristics and materials & energy needs of each process for efficient operation.

The inherent traits of these disparate process routes will limit the long term sustainability of steelmaking operation. Considering these limitations, the midi-mill process, which has a production capacity of approximately 2 MTPY, could be of great interest to potential investors. The process entails the use of alternative ironmaking processes that allow greater flexibility in raw material feed. FINEX can use fine ore and diverse carbonaceous material including low-ranking coal.

Table 1. Needs and Characteristics of Maxi-mill and Mini-mill Process Routes

<table>
<thead>
<tr>
<th>Description</th>
<th>Maxi-mill</th>
<th>Mini-mill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials and energy needs</td>
<td>High-quality lump, sintered, pelletized iron ores, Coking coal and limestone</td>
<td>High-quality scrap Steady power supply and infrastructure Electricity: 800 kWh/ton-steel</td>
</tr>
<tr>
<td>Coal :700 kg/ton-steel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Process and product characteristics</td>
<td>High production capacity (&gt; 3MTPY) De-[S], De-[P] processes required</td>
<td>Low production capacity (&lt; 1.5 MTPY) Homogenization of temperature and chemical composition delayed Long products, Ordinary grade steels</td>
</tr>
<tr>
<td></td>
<td>High-value added product</td>
<td></td>
</tr>
<tr>
<td>Greenfield plant cost estimate</td>
<td>USD 3500 million *3.0MTPY (BF, Sinter, Coke, BOF, Slab Caster, HSM)</td>
<td>USD 700 million *1.0MTPY (EAF, Bloom Caster, Billet Section mill, Rod &amp; Shape mill)</td>
</tr>
</tbody>
</table>
and fine coke made by 100% semi-coking coal, which are not used in the blast furnace operation. Therefore, a steel company which has operated BF can create synergy by adopting FINEX. This alternative midi-mill process route would be highly cost effective, considering capital and environmental costs associated with the coke-making and sintering operations, electricity costs and supply limit of high-quality scrap, and the demand for higher value-added steels.

The commercially proven alternative iron-making processes with 1.5-2 MTPY capacity are the Midrex and the HYL (Hojalata y Lamina) and the FINEX process. The Midrex and the HYL processes typically utilize natural or shale gas, which have been reformed into enriched H₂ and CO gases that provide reducing agents for full indirect reduction of iron ore. They are unable to treat iron ore fines and powder and are typically operated with pellets or lumpy ores to produce solid direct reduced iron (DRI). This DRI product can be fed into the EAF at moderately high temperatures above 600 °C with varying carbon contents less than 3 wt% by a specialized transport system at an additional cost. In the FINEX process, iron ore fines are directly charged into the fluidized bed reactor, partially reduced with CO and H₂ gases generated from the coal and oxygen reaction in the melter-gasifier, and subsequently fully reduced within the melter-gasifier. Unlike DRI production of the Midrex and the HYL, FINEX produces hot metal in the liquid state, which is comparatively simpler to handle than the hot solid DRI transport and expedites rapid heat transfer to the scrap in the steelmaking process. While the Midrex and the HYL are batch processes, FINEX is a continuous process and typically yields greater productivity. Thus, the FINEX process can be better positioned than the Midrex and the HYL in terms of operational flexibility and energy consumption for producing iron.

To achieve high throughput, the midi-mill operation can introduce high speed casting and endless rolling technology. According to research in the conventional batch rolling processes, the strips at the head and tail ends are
vulnerable to quality problems since tension is not applied at these regions. In addition, pincher defects are prevalent at the tail ends, reducing productivity and instigating work roll damage. These problems are significantly reduced, when the endless rolling process is incorporated downstream. By utilizing the latent heat in thin slab sent directly to the rolling process after the continuous casting machine, energy consumption and associated costs are estimated to be lower by up to 45% than those of conventional casting, which can result in significant CO₂ reductions. The midi-mill plant can also be highly compact in the rolling operation adopting this process. The compact endless casting and rolling mill (CEM) developed by POSCO and licensed to SMS group takes advantage of high throughput and energy efficiency of the thin slab caster and endless rolling process combination. CEM allows production of ultra-thin gauge hot-rolled products, operating in both batch and endless modes, and reduces investment costs, energy consumption, and carbon dioxide emissions, as shown in Figure 1.

**Sustainability issues of raw materials**
The increase in global steel production has resulted in the greater use of high-grade raw materials, but their limited availability hinders steel production sustainability. Therefore, it will be unavoidable to use lower grade raw materials with greater gangue content in iron ore and low-grade metallurgical coals in the near future. This puts greater pressure on beneficiation in raw materials, which would entail greater energy use and higher costs. And even with better beneficiation technology, the resulting gangue content and higher phosphorous and sulfur have required the existing ironmaking and steelmaking technologies to improve their refining capacities. However, with stronger environmental restrictions, the efficient and cost-effective methods presently used cannot

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**Figure 1. Comparison between FINEX/CEM and Conventional Mill**

<table>
<thead>
<tr>
<th>Area</th>
<th>CAPEX</th>
<th>OPEX</th>
<th>SOx</th>
<th>NOx</th>
<th>Dust</th>
</tr>
</thead>
<tbody>
<tr>
<td>FINEXBF</td>
<td>80%</td>
<td>85%</td>
<td>85%</td>
<td>6%</td>
<td>9%</td>
</tr>
<tr>
<td>Conventional CEM</td>
<td>85%</td>
<td>9%</td>
<td>59%</td>
<td>40%</td>
<td>85%</td>
</tr>
</tbody>
</table>

*Comparison with Annual 3MTPY constructed in Korea*

<table>
<thead>
<tr>
<th>Area</th>
<th>CAPEX</th>
<th>Energy</th>
<th>CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>FINEXBF</td>
<td>85%</td>
<td>50%</td>
<td>85%</td>
</tr>
<tr>
<td>Conventional CEM</td>
<td>85%</td>
<td>50%</td>
<td>85%</td>
</tr>
</tbody>
</table>

*Comparison with Annual 2MTPY*
overcome this increased impurity contained in raw materials.

Higher gangue content in raw materials requires greater input of limestone to counteract and balance the composition of slag for optimal fluidity and separation of slag from metal. Unfortunately, the addition of fluxes to counteract the increased gangue content will result in the greater slag volume, which will limit the production capacity of the reactor. In addition, slag will require more heating and greater carbon usage, resulting in lower energy efficiency and greater CO₂ emissions. Also, depending on the ore particle size and strength of low-grade raw materials in the maxi-mill process route, significant operational issues may arise. Thus, for the maxi-mill process incorporating the blast furnace, the availability of high-quality raw materials is necessary for optimal and cost-effective operations.

High-quality steel scraps for the production of higher value-added steel products must be satisfied in the long term for sustainable mini-mill operations. As consumer products rely more on electronics, information technology products, and pre-cooked foods, the available scrap can contain significant amounts of tramp elements, copper, and tin, which are difficult to remove under the oxidizing atmosphere of typical refining operations. Alternative iron units are typically added to the mini-mill process to substitute scrap, when high-quality steel products are needed. Iron units of DRI or hot briquetted iron (HBI) can be used or, if available, pig iron units can be utilized. The addition of large amounts of iron units with high carbon content can result in the greater need of oxygen injection and lower energy consumption.

Sustainability issues of energy and the environment

According to a report by the International Energy Agency (IEA), global renewable energy accounts for only 10% of power generation. The bulk of energy production still comes from coal and oil, which emit significant amounts of CO₂. Unlike the maxi-mill process, where most of the CO₂ is direct CO₂ from carbon use for energy and reduc-
tion, the mini-mill process utilizes electricity and this particular process route emits indirect CO₂. It is well established that approximately 1.8 ton CO₂/ton-HM is generated in the maxi-mill and 1.1 ton CO₂/ton-HM is generated in the mini-mill.

During the 2015 United Nations Climate Change Conference or COP21 held in Paris, member countries agreed on a common carbon trading scheme that would affect the global CO₂ emissions. The pricing of excess CO₂ would see uniform costs charged for every ton of excess CO₂ emitted beyond the allocated amount set forth by the individual countries. This eventually would lead to significant cost issues due to environmental regulations and thus process routes capable of lowering the CO₂ emissions would be highly favored. Unfortunately for the blast furnace, the dominance of coke as the energy and reductant source in the maxi-mill process limits its reducing potential of CO₂ emissions in the long term. The recent progress with top-gas recycling and hydrogen-containing gas injection into the furnace allows to lower CO₂ emissions, but its effect has yet to be tested in the commercial scale.

Operational flexibility during economic up- and down-turns

Global steel production exceeded 1.6 billion tonnes in 2015 and excess capacity has reduced the profitability of steel companies. Excess supply in the market has dragged down steel prices and overcompetition has led to the dumping of steel products into foreign markets, disrupting normal market conditions. Thus, cost-effective reduction in steel production is necessary during a down-turn.

For the maxi-mill process, the BF is limited in decreasing the capacity below 90% of total production capacity to maintain cost-effectiveness. The mini-mill process, on the other hand, has robust flexibility in start-up and shut-down of operations. Depending on market conditions, the EAF can be shut down for intermittent periods and restarted. When power outages occurred in the late 2010, EAF was operated only during weekends to lower power burden. However, the mini-mill process has a limited production capacity during economic up-turns, when the maximum production capacity is needed. Therefore, future process should have sufficient production during economic up-turns and have flexibility to control production during economic down-turns. This suggests that future process should adopt a process route that lies somewhere between the maxi-mill and mini-mills; that is, a midi-mill configuration with a production capacity over 2 MTPY and operational flexibility.

Hybridization of individually optimized processes to create synergy

In proposing the next generation midi-mill process with high productivity and flexibility, the FINEX alternative ironmaking technology can be connected to the EAF or BOF, as shown in Figure 2. Hot metal produced from the melter-gasifier of FINEX has comparable chemical composition to the products from the BF. Table 2 shows the typical composition of hot metal and slag of FINEX. Similar to the BF process routes, FINEX can be connected to the BOF for primary refining and decarburization to attain a production capacity of approximately 2 MTPY. FINEX can also be connected to the EAF, where hot metal is
added with the scrap to lower overall power consumption in typical EAF processes. Depending on the amount of hot metal used, decarburization through oxygen injection must be optimized with productivity. Greater amounts of hot metal will lower the power consumption needed, but the tap-to-tap time can be extended due to the excessive decarburization time needed within the EAF. Secondary steelmaking should be similar for both FINEX-BOF and FINEX-EAF routes.

After secondary steelmaking, molten steel is solidified in the continuous casting machine for subsequent heating and rolling or be optionally connected to a highly efficient CEM process. CEM allows mass production of highly valuable hot-rolled products by directly connecting a single strand thin slab casting line with a rolling line. Maximum casting speeds above 8.0 m/min at 80 mm slab thickness can be achieved for ultra-thin gauge hot coils. Various steel grades like low carbon (LC), medium carbon (MC), high carbon (HC), high strength low alloy (HSLA), and advanced high strength steel (AHSS) can be produced. CEM can operate in both batch and endless rolling modes. The endless rolling mode is selected for thin-gauge products and the batch rolling mode is for thick-gauge products or certain special steel grades. High throughput and greater energy efficiency with the installation of CEM in the midi-mill process would allow the cost-competitive operation to produce broad ranges of high-quality products.

What is FINEX?
The FINEX process, which is illustrated in detail in Figure 3, can use non-coking low rank coals, which are compacted into briquettes of approximately 50 mm. The coal briquettes are charged into the melter-gasifier and combusted with unheated pure oxygen. Pulverized coal injection (PCI) can be used similar to the BF to improve heat efficiency. Depending on the size
bution and characteristics of iron ore fines, the amount and ratio of hot gases must be controlled for effective fluidization and reduction. Unlike the blast furnace, fluidized bed technology allows the use of low-quality iron ore, but it is difficult to reduce magnetite. However, the FINEX process consumes greater amounts of coal and requires oxygen to balance the heat in the melter-gasifier and fluidized particles in the reactor.

Hot gases generated within the melter-gasifier are initially supplied into the first reactor (R1) passing through the second (R2) and the third (R3) reactor of the multi-stage fluidized bed. As expected, the reducing potential of gases changes by the individual reactor and thus the sufficient amount of gases must be generated within the melter-gasifier for fluidization, heat transfer, and reducing potential. Ore fines are first pre-heated in R3 to approximately 450°C, pre-reduced in R2 to about 20% reduction and 650°C, and finally reduced in R1 to a maximum reduction of about 80% and 750°C. The DRI fines from R1 are compacted into hot compacted iron (HCI) and then charged into the melter-gasifier. HCI is smelted in the melter-gasifier into hot metal and the gangue is separated towards the slag phase. Table 2 shows the typical hot metal composition and slag made from diverse raw materials by the commercial FINEX.

Within each fluidized bed reactor, a gas distributor plate evenly supplies hot-reducing gases to transform the solid particles into a fluid-like state, resulting in uniform temperature, composition, and particle distribution within the reactor. The gas passes through a top cyclone and is connected to the bottom of a subsequent reactor. Depending on coal rank, the composition of gas may vary within each reactor and affect the overall gaseous species produced. Depending on the resources available, iron ores can be varied from hematite, magnetite, ilmenite, and others.

FINEX typically uses 100% iron ore fines, but...
it can tap slags containing higher alumina. This is an advantage in regions where iron ore with high alumina content is abundant such as India and China.

Due to the simplicity of FINEX, initial investment can be dramatically reduced in comparison to a conventional BF. Additional cost savings can be realized with the utilization of less costly low-quality raw materials. Shut-down and start-up is also comparatively simpler than the conventional blast furnace route. Thus, operating costs of FINEX is estimated to be 15% lower than the conventional blast furnace based on operational data.

**Eco-steel production in FINEX using high hydrogen reducing gases and CCS**

Compared to the integrated maxi-mill process, the FINEX process has higher potential to use high volatile containing coals as well as hydrogen enriched gases. The available hydrogen can increase the productivity of hot metal production with lower carbon input into the reactor, which

<table>
<thead>
<tr>
<th>Product</th>
<th>Si (wt%)</th>
<th>S (wt%)</th>
<th>P (wt%)</th>
<th>Tap Temp ('C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot metal</td>
<td>1.2</td>
<td>0.05</td>
<td>0.130</td>
<td>1,500</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product</th>
<th>C/S</th>
<th>Al₂O₃ (wt%)</th>
<th>Volume (kg/t-hm)</th>
<th>Tap Temp ('C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slag</td>
<td>1.1</td>
<td>17.7</td>
<td>320</td>
<td>1,520</td>
</tr>
</tbody>
</table>

Table 2. Hot Metal and Slag Composition of the 1.5 Mt Capacity FINEX Operation in POSCO Pohang Steelworks

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Figure 4. Eco-strategy of FINEX using High Hydrogen Reducing Gases and CCS

- **Present Status (No. 1 & No. 2 FINEX®)**
- **Short-term Plan (R&D)**
- **Long-term Plan (Commercial)**

- Removal of CO₂ in off gas, Reuse of product gas for reduction gas
- Application and commercialization of CCS technology
Due to the simplicity of FINEX, initial investment can be dramatically reduced in comparison to a conventional BF. Additional cost savings can be realized with the utilization of less costly low quality raw materials.

can be highly advantageous as global environmental regulations become increasingly stringent and carbon tax trading schemes become more common.

Typical strategies for future steelmakers will likely require alternative ironmaking units that can supply hot metal to the converter with less carbon footprint. The obvious choice to satisfy these conditions will likely be the FINEX process, as illustrated in Figure 4.

Similar to the BF process, generation of CO₂ gas from FINEX is inevitable due to the use of coal, which is the main heat source and reducing agent. Therefore, reducing the amount of CO₂ emissions is one of the main priorities of FINEX.

If a commercial scale, cost-effective carbon capture and storage (CCS) technology is developed, FINEX will likely be the most favorable process to reduce CO₂ emissions. This is due to the simpler application of the CCS technology to the FINEX operation since it uses pure oxygen, which enriches the CO₂ exit-gas and the recycling technology of off-gas after separating CO₂ from the pressure swing absorption (PSA) system which currently exists.

What is so special about CEM?
In the early 1990s, the mini-mill process and subsequently the EAF technology was in the spotlight for its robustness in small scale production with wide product variation at greater energy efficiency and lower carbon emissions. POSCO operated the in-line strip production (ISP) mini-mill plant for producing commercial steel from 1996 at Gwangyang Steelworks. Facing limitations in manufacturing high-quality thin gauge products, it underwent a revamp from a two strand to one strand caster. This required POSCO to invest in the development of high-speed casting technology to balance the mass throughput of the caster and hot-rolling mill. As a result of this effort, the current CEM was developed in 2011 with the installation of a high speed shear that enables endless rolling. The details of the CEM process configuration are shown in Figure 5. A single-strand casting and a single-strand rolling are directly
linked. The major equipment includes: continuous caster, slab shear, slab heater, 4-Hi roughing mill, bar shear, bar heater, 4-Hi finishing mill, run out table, high speed shear, and down coiler.

Thin slabs with 90~110 mm thickness is rolled in-line through three sets of 4-Hi roughing mills, which decrease the thickness to 15~40 mm. In the finishing mill, the bar is rolled into a strip and its thickness is reduced to 0.8~20 mm. Laminar flow cooling allows the control of the desired mechanical properties.

CEM operates in both batch and endless rolling modes depending on the thickness and products. These two rolling modes are freely convertible at any time even in operation without any equipment exchange or installation. This increases flexibility of CEM compared to a conventional casting and hot strip mill and rolling assists steelmakers to adequately compensate its operation in an unpredictable and rapidly changing market.

The batch rolling mode of CEM is mainly for thick-gauge products. The endless rolling mode is mainly for thin-gauge products, where the as-cast steel strand is connected to the rolling mill and continuously wound to the down coilers without delays until the strip is cut by the high speed shear. This mode can secure stable rolling especially for thin gauges due to the significantly reduced strip threading and tail out operations.

Due to the high speed casting and endless rolling operational conditions, synchronized control of the process from casting to rolling is crucial. To produce high-quality steel and increase productivity conducive for the midi-mill process, the integrated thin slab caster and the CEM operation requires optimal control of the molten steel flow in the mold, homogeneous steel solidification in the mold and strand secondary cooling, and breakout prediction and prevention during casting. These conditions can connect to synchronized strip tension control, precise temperature
prediction and control, high-speed shearing and instant coiler switching, inductive heating control using specific temperature models, accurate gauge control, work roll thermal crown and wear control, strip flatness control and optimal descaling for surface quality.

POSCO has done a lot of work in expanding the range of CEM products to meet market demands. Through the development of CEM, it can produce a variety of steel grades from LC, MC, and HC to HSLA, AHSS, silicon steel, and others. CEM is used widely in pipes, structural parts, automobile components, tools, and weathering components. It is possible to make products as thin as 0.8 mm, and the endless rolling mode is selected for most thin gauge products below 2.0 mm.

Especially, it is efficient to produce AHSS such as dual phase (DP), ferrite bainite (FB), martensite (MART) steel, which is sensitive to strip cooling conditions in run out table and coiling temperature by CEM endless rolling. In the conventional hot-rolling mode, the acceleration of rolling speed is necessary to compensate for the temperature drop at the strip tail, and two-step cooling is performed to control the microstructure. On the contrary, in the CEM endless rolling mode, constant speed rolling is possible and homogenous quality of strip from the head to the tail is achievable because the strip tension can be retained constantly throughout the process even in the cooling zone of the run-out table. One-step cooling is enough to generate two disparate phases of steel at a lower rolling speed than that of the conventional batch rolling. Productivity is unchanged because a decrease in the rolling speed is unnecessary in the CEM endless rolling mode. The strip is uniformly cooled over the entire strip length, and uniform quality and high yield can be obtained. Figure 6 demonstrates that the actual results of mechanical properties composed of tensile
strength for the x-axis and total elongation for the y-axis.

**How to efficiently utilize the midi-mill process route**

Under the current oversupply and strengthened environmental regulations, it is burdensome for steelmakers to consider new investment in the maxi-mill (combination of a traditional BF and hot-rolling mill). In the mini-mill process, there are some limitations in producing flat steel products due to harmful tramp elements in raw materials of scrap and high electricity costs. Table 3 shows how we can combine FINEX and CEM for the steel making process.

FINEX may offer an opportunity for steelmakers to design an eco-friendly, small and medium-sized hot metal production of an integrated steel mill in regions, where only low-grade iron ore and coals are available. It is also possible to implement power generation projects by increasing the use of lower grade coal with high volatile contents, so that it creates more off-gas to generate electricity, where there is a lack of power.

The recent trend in hot coil demand is shifting towards high-strength, thin gauge, and wide width to increase the fuel efficiency in the automotive sector, minimize the labor intensity in shipbuilding or construction sites, and improve the production yield of pipe or tube. In Europe, demand for 0.8~1.2 mm ultra-thin gauge black coils has continued to increase for pickling, oiling, or hot-dip galvanized products. This gauge range was traditionally considered as the sole territory of cold-rolled products, but with further development, it will be able to be substituted by hot-rolled products in the future due to its highly competitive price.

The CEM process, which produces 1.5-2.5 MTPY of hot-rolled coil, can be installed at low

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**Table 3. Application of the FINEX-CEM Combined Midi-mill Process**

<table>
<thead>
<tr>
<th>Process</th>
<th>Application</th>
</tr>
</thead>
</table>
| **FINEX** | - BF companies which increase iron making capacity (mutual supplement with BF)  
- Steel makers which need a small and mid-scale upstream process  
- Companies that sell pig iron and electric power  
- Regions with low grade iron ore and coal  
- Regions under strict environmental regulations  
(Difficult to build a new sinter and coke plant) |
| **CEM** | - Companies which increase hot strip production capacity  
(synergy with existing Hot Strip Mill)  
- Companies that need a compact & competitive mid-scale HSM with wide product spectrum  
- Companies that plan to revamp a old thin slab caster |
| **FINEX & CEM-based steel mill** | - Including above  
- Companies that build a compact & competitive mid-scale integrated steel mill |
investment costs. It also has an advantage of stable mass production in high-quality thin gauge steel for various steel grades like LC, MC, HC, HSLA, AHSS and even Si steel by the utilization of high speed casting and endless rolling technology. This is difficult for a conventional hot-rolling mill, because of the sharp decline in productivity, added operational troubles, and poor quality in the head and tail portion of hot coil.

If maxi-mills that operate only conventional hot-rolling mills in the CEM process adopts FINEX, productivity can be remarkably increased. Through the hybridization of the FINEX and CEM processes, a midi-mill can have strong competitiveness by lowering capital expenditures (CAPEX) and operating expenses (OPEX), and can have a wide range of products in steel grades and thickness. It will also allow significant flexibility of raw material feeding.

The midi-mill process creating synergy with existing processes

Since 2008, the global steel industry has faced unprecedented and unpredictable challenges such as steel oversupply, protectionism, and strict environmental regulations. In order to overcome these barriers and ensure continued steel sustainability, the existing maxi-mill and mini-mill process routes cannot be a solution. Instead, it is necessary to take advantage from the individual maxi- and mini-mill processes and minimize disadvantages to make a new sustainable process more agile to the dynamic business surroundings. Thus, the 1.5-2 MTPY midi-mill process route with disruptive technologies can be an effective alternative, as it creates synergy with existing processes.

FINEX and CEM are compact processes by eliminating or combining the conventional processes. They can reduce investment costs, operational costs, and environmental emissions. FINEX has more flexibility in raw materials and operations than the blast furnace route and higher productivity than the EAF route. CEM can achieve high throughput and meet product requirements by converting from batch rolling to endless rolling. The midi-mill process route of the FINEX and CEM combination can satisfy the needs to build a steel plant which is medium-scale, economically competitive, raw material and operational flexibility, and eco-friendly.

Acknowledgements

Special appreciation is warranted to Prof. Il Sohn of the Department of Materials Science and Engineering at Yonsei University for his helpful comments and suggestions finalizing this work.
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88  Myanmar, the Last Frontier in the ASEAN, Will See High Growth of its Steel Industry  Dr. Cho, Dae-Hyun
The Demographic Cliff: How It Will Impact Asia’s Steel Demand

Dr. Chung, Cheol-Ho
Senior Principal Researcher
POSCO Research Institute
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Amid a prolonged slowdown of the global economy after the financial crisis of 2008-09, many people accept low growth as the new normal. What is the root cause of this slow growth that has lasted for an unprecedentedly long time? Many experts blame weak global demand, industrial overcapacity, and the world’s alarmingly high debt. However, there is one thing they often overlook: demographic changes that determine economic fundamentals.

Many renowned economists have referred to the importance of population: Peter Drucker, Harry Dent, Bill Gross, and Ruchir Sharma, to name a few. Management guru Peter Drucker emphasized the importance of population, saying that demographics is the most precise way to forecast the future.

Ruchir Sharma, Head of Emerging Markets and Chief Global Strategist at Morgan Stanley Investment Management, said in his report

Global Population by Age Group

Source: UN

Global GDP Growth and Working-age Population

Source: UN
to Foreign Affairs in March that demographic changes are the root cause of weak global economic growth, and a 1%p decline in population growth leads to a 0.5%p decline in economic growth. In economic terms, potential economic growth is comprised of increased input of labor and capital, as well as residual growth of total factor productivity. If there is no specific change in capital input or technological advancement, labor input determines potential economic growth.

In fact, the annual change in the global working-age population has a strong correlation with the global economic growth rate. Global population has continued to grow, and it will maintain an upward trend until 2100. However, the demographic structure is changing significantly, as evidenced by a rapid rise in the aged population and a stagnant young population. The annual change in the global working-age population peaked in the mid-2000s, and has declined since.

**Changes in working-age population influence economic growth. They are also presumed to have a direct impact on steel consumption, because the working-age population is the main consumer group of houses and vehicles, the key sources of steel demand. For example, home and car ownership statistics by age group in Korea show that people in their 40s and 50s account for 50-60% of total ownership. When people in their 30s are included, this figure even rises to 70-80%. This is in line with Harry Dent’s assertion that household consumption usually peaks in people’s mid to late 40s and demographic changes in this age group determine the future of the economy.**

By industry, construction accounts for the lion’s share of steel consumption in most countries. In India, Russia, and China, construction accounts for about 60% of steel consumption. In the USA, Japan, and other advanced countries, the share of construction is lower than that in developing countries, but is still high at around 40%.

The automotive industry’s share of steel consumption varies significantly by country: 25-30% in the USA and Japan, and 7.0% and 9.0% in China and India, respectively. This variation seems to be caused by differences in economic development phase and income levels. Like automobiles, home appliances are consumed mostly by people in their 30s-50s. The shipbuilding industry is expected to be directly affected by changes in the global economy and global shipping volume,
Asian Steel Watch

which have a strong correlation with changes in working-age population.

**Impacts of a changing working-age population:**

As stated earlier, the global population is projected to increase until 2100. However, the annual change in the working-age population will continue to decline, after having peaked in 2004. Considering strong correlations among working-age population, economic growth, and steel consumption, global steel consumption does not have a bright future in the medium to long term.

How does the situation differ by country? Which countries will see an increase in working-age population, and which countries will see a decrease?

With chronic low birth rates and aging populations, countries including Korea have already become an “aging society,” in which 7% or more of the population is 65 years old or older, and most advanced countries, including the USA, Japan, and European countries, have already reached an “aged society,” in which 14% or more of the population is 65 years old or older. In particular, Japan, Germany, Italy, Greece, and Portugal have “super-aged societies,” in which 20% or more of the population is 65 years old or older. France

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**Population Aging by Region (2015)**

<table>
<thead>
<tr>
<th>Region</th>
<th>Super-aged societies</th>
<th>Aged societies</th>
<th>Aging societies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia</td>
<td>Japan</td>
<td>Hong Kong</td>
<td>South Korea, Singapore, China, Thailand, North Korea, Sri Lanka, Macau</td>
</tr>
<tr>
<td>Europe</td>
<td>Germany, Italy, Greece, Portugal, Finland, Bulgaria</td>
<td>Sweden, Latvia, Malta, France, Denmark, Croatia, Lithuania, Spain, Estonia, Austria, Netherlands, Belgium, Czech Republic, Switzerland, Slovenia, Hungary, UK, Romania, Serbia, Norway, Poland, Bosnia</td>
<td>Luxembourg, Slovakia, Iceland, Montenegro, Ireland, Albania, Turkey, Colombia, El Salvador, Moldova</td>
</tr>
<tr>
<td>Americas</td>
<td>USA, Canada, Uruguay</td>
<td>Australia, New Zealand</td>
<td>Chile, Argentina, Cuba, Jamaica, Costa Rica, Brazil, Panama, Bahamas, Trinidad and Tobago, Guam</td>
</tr>
<tr>
<td>Oceania</td>
<td>Australia, New Zealand</td>
<td></td>
<td>Russia, Belarus, Armenia</td>
</tr>
<tr>
<td>CIS</td>
<td>Ukraine, Georgia</td>
<td></td>
<td>Israel, Lebanon, Cyprus</td>
</tr>
<tr>
<td>Middle East</td>
<td></td>
<td></td>
<td>Mauritius, Tunisia</td>
</tr>
<tr>
<td>Africa</td>
<td></td>
<td></td>
<td>Source: World Population Prospects, the 2015 Revision, UN</td>
</tr>
</tbody>
</table>

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**Share of Manufacturing to GDP (1970-2014)**

![Graph showing the share of manufacturing to GDP for Japan, UK, USA, Italy, and France from 1970 to 2014](Source: UNCTAD)
and Spain will have super-aged societies in 2018, while the UK and the USA will have super-aged societies in 2027 and 2028, respectively. These advanced countries have already experienced various economic and social problems caused by low birth rates and aging populations. In Europe, the aging workforce in the steel sector has become a major issue.

In Germany, 35.3% of the workforce (302,133) in the steel and non-ferrous metal industries is 50 years old or older, and 19.4% is 55 years old or older in 2013. The work load, safety, and health problems of aged workers are key issues in Germany.

It is hard to generalize the experience of population aging in advanced countries, but there are some characteristics in common: the share of manufacturing shrinks in the economic structure, while the share of service increases; and steel consumption declines after a peak.

However, the peak of steel consumption does not match the peak of the working-age population in some countries. This is attributed to differences in immigration policies and economic participation by women. In the case of Europe, the variation is attributed to the launch of the EU, which has promoted economic integration and free movement of persons. In addition, countries’ different industrial structures (i.e. share of manufacturing) and dependence on investment or trade can cause differences in the relationship between steel consumption and working-age population.

### Pace of Population Aging

<table>
<thead>
<tr>
<th>Country</th>
<th>The year reached to</th>
<th>Years taken</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aging Society (7%)</td>
<td>7→14%</td>
</tr>
<tr>
<td></td>
<td>Aged Society (14%)</td>
<td>14→20%</td>
</tr>
<tr>
<td>Germany</td>
<td>1932</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>1972</td>
<td>36</td>
</tr>
<tr>
<td>UK</td>
<td>1929</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>1975</td>
<td>52</td>
</tr>
<tr>
<td>France</td>
<td>1884</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td>1979</td>
<td>39</td>
</tr>
<tr>
<td>Italy</td>
<td>1927</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>1987</td>
<td>19</td>
</tr>
<tr>
<td>Portugal</td>
<td>1950</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>1990</td>
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<tr>
<td>Greece</td>
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<tr>
<td></td>
<td>1990</td>
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</tr>
<tr>
<td>Spain</td>
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<tr>
<td></td>
<td>1991</td>
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<td>Japan</td>
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<td></td>
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<tr>
<td>Canada</td>
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</tr>
<tr>
<td></td>
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</tr>
<tr>
<td>USA</td>
<td>1942</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>2014</td>
<td>14</td>
</tr>
</tbody>
</table>

Source: Japan National Institute of Population and Social Security Research; Population Statistics (2016), UN

### Working-age Population and Steel Consumption Peaks

<table>
<thead>
<tr>
<th>Country</th>
<th>Working-age population peak</th>
<th>Steel consumption peak</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Population</td>
<td>Share</td>
</tr>
<tr>
<td>USA</td>
<td>Not arrived</td>
<td>2008</td>
</tr>
</tbody>
</table>

Source: worldsteel, UN
How is working-age population changing in Asia, which is leading the growth of the global steel industry? What influences do these changes have on each country’s steel industry?

Japan is the world’s most aged society, and its population will continue to age. Japan’s working-age population began to decline in 1996, and its total population began to fall in 2010. In 2005, the percentage of people aged 65 years or over reached 20%, the threshold for a super-aged society. In 2015, it reached 26.3%, the highest in the world. This percentage will continue to rise, reaching 30.4% in 2030, and 36.3% in 2050.

Both economic growth rate and steel consumption in Japan have a strong correlation with changes in working-age population. From 1950 to 2015, the correlation between economic growth rate and annual increase in working-age population was quite strong with a coefficient of 0.79, and the correlation between steel consumption and the proportion of working-age population was 0.61.

Source: UN
Changes in working-age population influence economic growth. They are also presumed to have a direct impact on steel consumption.

Changes in the construction and automotive industries—Japan’s major steel-consuming industries—have a strong correlation with changes in the working-age population. First, the correlation between the number of construction starts of dwellings and proportion of working-age population was high with a coefficient of 0.68 in 1965-2014, and these two variables had similar peaks. The correlation between the number of automobiles registered and proportion of working-age population was relatively low with a coefficient of 0.2, but the peak in number of automobiles reg-

![Graph: Japan’s Construction Demand and Working-age Population](source)

![Graph: Japan’s Automobile Demand and Working-age Population](source)
registered in 1990 nearly coincided with the peak in working-age population in 1992.

Just like Japan, Korea and China have rapidly aging populations. This trend will last for a while. In 2015, Korea’s total fertility rate stood at 1.24 persons, among the lowest in the world. The number of births was 439,000 in 2015, down 50% compared to 1980. The number of births declined especially rapidly after the 1998 financial crisis. Korea’s working-age population is expected to shrink from 2017, and its total population is projected to decline in 2031. In 1998, Korea became an aging society, and in 2016 it is projected to become an aged society. Korea will likely become a super-aged society in 2025.

Like Japan, Korea has a strong correlation between economic growth rate and annual change in working-age population, and between steel consumption and proportion of working-age population. The projected decline in working-age
The Demographic Cliff: How It Will Impact Asia’s Steel Demand

Population in 2017 and the acceleration of decline thereafter, will have a negative impact on economic growth and steel consumption. The future is not bright for the construction and automotive industries. Korea’s home ownership rate exceeded 100% in 2008. Domestic automotive production remained stagnant after recording 4.657 million units in 2011, standing at 4.556 million units in 2015. Korea’s urbanization rate is already considerably high at 85%, and its infrastructure rate, including railroads, roads, and airports, is also high. Therefore, these factors have little room for growth. The decline in the number of consumers of houses and vehicles caused by the shrinking working-age population will negatively impact steel demand.

China also has bleak forecast for steel demand given demographic trends. China’s working-age population peaked in 2014. It has fallen since, and will maintain a downward trend. China’s total population is also expected to decline, after peaking at 1.416 billion in 2027. The proportion of working-age population peaked at 74.4% in 2011,

Infrastructure Comparison Between China and G7

<table>
<thead>
<tr>
<th></th>
<th>China (A)</th>
<th>G7 (B)</th>
<th>A/B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road mileage (km/1,000 people)</td>
<td>330</td>
<td>1,390</td>
<td>24%</td>
</tr>
<tr>
<td>Railway mileage (km/1,000 people)</td>
<td>8.2</td>
<td>53</td>
<td>15%</td>
</tr>
<tr>
<td>Pipeline length (km/1,000 people)</td>
<td>7.7</td>
<td>86.3</td>
<td>9%</td>
</tr>
<tr>
<td>Airport density (per 1,000km²)</td>
<td>2.1</td>
<td>95.1</td>
<td>2%</td>
</tr>
<tr>
<td>Internet bandwidth per capita (kb/s)</td>
<td>5</td>
<td>163</td>
<td>3%</td>
</tr>
<tr>
<td>Electricity consumption per capita (KWh)</td>
<td>3,475</td>
<td>8,826</td>
<td>39%</td>
</tr>
</tbody>
</table>

Source: Excerpt from a presentation by Jiang Li at a worldsteel Economic Committee meeting
and has declined since, while steel consumption peaked in 2013 and declined in 2014 and 2015. According to worldsteel, China’s steel consumption is also expected to decline in 2016 and 2017. The continuous decline in the proportion of working-age population warns of a bleak future for China’s steel consumption in the medium to long term.

However, China’s urbanization rate is relatively low, and its infrastructure is less developed than that of advanced countries. There is the possibility that new steel demand will emerge if current severe overcapacity is relieved.

Fortunately, unlike Korea, China, and Japan, the steel demand forecast for India and the ASEAN is bright, given current demographic trends.

By 2022, India will eclipse China to become the world’s most populous country, reaching 1.418 billion people, and it will surpass China in terms of working-age population in 2025. India’s working-age population is projected to increase until 2052, peaking at 1.145 billion, and gradually decline thereafter. The proportion of working-age population in total population is expected to peak at 68% in 2040 and fall gradually thereafter. Therefore, India is anticipated to offset the shock of China’s falling working-age population to an extent, and to maintain higher growth in steel demand than other countries. India’s finished steel demand surged after the 2000s, standing at 91 Mt as of 2015. For reference, India’s annual average growth rate of steel consumption was 7.6% from 2000 to 2015. Taking into account the upward trend in population, steel demand is expected to grow at least 5% by 2030, and steel consumption is expected to reach almost 200 Mt by 2030.

The ASEAN countries, except for a few aging countries, including Thailand and Singapore, also have bright futures for steel demand, given current demographic trends. Thailand and Sin-
The ASEAN countries, except for a few aging countries, including Thailand and Singapore, also have bright futures for steel demand, given current demographic trends.

gapore’s working-age populations are projected to peak in 2017 and 2021, respectively. The projected peak is much later for other countries: 2036-2038 for Brunei and Vietnam, around 2050 for Malaysia, Myanmar, and Laos, and as late as 2060-2080 for Indonesia, Cambodia, and the Philippines.

The total working-age population of the ASEAN-10 stood at 427 million people in 2015. It is projected to grow to 486.84 million people in 2030, an increase of about 60 million people. Indonesia will be the largest contributor to this increase, followed by the Philippines, Myanmar, Vietnam, Malaysia, and Cambodia.

In 2015, finished steel consumption in the ASEAN-7 (excluding Brunei, Cambodia, and Laos) reached 70 Mt, which is higher than in Korea (56 Mt) and Japan (62.94 Mt). Assuming that steel consumption will increase by at least 5% on average each year, steel consumption is expected to reach 145 Mt in 2030.

Indonesia, the Philippines, Vietnam, and
India and the ASEAN in 2015. This means that if demand in Korea, China, and Japan declines by 5%, demand in India and the ASEAN must increase by as much as 25% for total steel demand to remain constant. It is unlikely that India and the ASEAN’s demand will grow fast enough to offset the decline in steel demand in the three East Asian countries.

This suggests that the Asian steel industry will not escape its bind any time soon, making it all the more necessary to address overcapacity. Even if supply declines in proportion to falling demand, overcapacity will remain the same.

How should steelmakers in countries on the brink of the demographic cliff respond to this situation? Conditions may vary by country, but there are some common solutions: developing high value-added products through technological innovation, improving labor productivity, saving costs, adopting solution marketing, distributing risks through globalization, diversifying businesses, and preparing for the aging workforce.

The fourth Industrial Revolution, which is

### ASEAN’s Population Aging and Key Economic and Steel Indicators

<table>
<thead>
<tr>
<th>Country</th>
<th>The year reached to</th>
<th>Economic &amp; steel indicators (2015)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aging society (7%)</td>
<td>Aged society (14%)</td>
</tr>
<tr>
<td>Singapore</td>
<td>1997</td>
<td>2018</td>
</tr>
<tr>
<td>Thailand</td>
<td>2000</td>
<td>2021</td>
</tr>
<tr>
<td>Vietnam</td>
<td>2001</td>
<td>2033</td>
</tr>
<tr>
<td>Malaysia</td>
<td>2018</td>
<td>2043</td>
</tr>
<tr>
<td>Brunei</td>
<td>2021</td>
<td>2034</td>
</tr>
<tr>
<td>Myanmar</td>
<td>2021</td>
<td>2051</td>
</tr>
<tr>
<td>Indonesia</td>
<td>2023</td>
<td>2048</td>
</tr>
<tr>
<td>Cambodia</td>
<td>2029</td>
<td>2052</td>
</tr>
<tr>
<td>Philippines</td>
<td>2029</td>
<td>2068</td>
</tr>
<tr>
<td>Laos</td>
<td>2038</td>
<td>2059</td>
</tr>
</tbody>
</table>

Note: *Myanmar’s nominal steel consumption is based on 2014 data
Source: UN, IMF, worldsteel, SEAISI

Myanmar, which have rapidly growing working-age populations, are expected to see their steel consumption grow significantly.

In particular, Vietnam, Myanmar, and the Philippines have per capita incomes of less than USD 3,000, and low urbanization rates, 30-50%. Therefore, steel consumption in these countries will grow especially quickly.

#### Increasing productivity and globalization to mitigate effects of population decline

The decrease in working-age population in Korea, China, and Japan, which have led growth of the global steel industry until now, will have a negative impact on global steel demand in the medium to long term. However, India and the ASEAN, whose working-age populations continue to grow, will buffer the shock from the demographic cliff in the three East Asian countries.

Korea, China, and Japan’s total finished steel demand was five times the total steel demand of India and the ASEAN in 2015. This means that if demand in Korea, China, and Japan declines by 5%, demand in India and the ASEAN must increase by as much as 25% for total steel demand to remain constant. It is unlikely that India and the ASEAN’s demand will grow fast enough to offset the decline in steel demand in the three East Asian countries.

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How should steelmakers in countries on the brink of the demographic cliff respond to this situation? Conditions may vary by country, but there are some common solutions: developing high value-added products through technological innovation, improving labor productivity, saving costs, adopting solution marketing, distributing risks through globalization, diversifying businesses, and preparing for the aging workforce.

The fourth Industrial Revolution, which is
It is unlikely that India and the ASEAN’s demand will grow fast enough to offset the decline in steel demand in the three East Asian countries. This suggests that the Asian steel industry will not escape its bind any time soon, making it all the more necessary to address overcapacity.

characterized by the integration of manufacturing and IoT, and smart factories, will provide the steel industry with a new growth engine that will mitigate the effects of population decline. Companies seeking global expansion to overcome the limitations of domestic markets must consider the demographic trends of the countries they wish to enter, because demographic changes determine the fundamentals of steel demand. In addition, taking into account the gloomy forecast diversifying their businesses into promising industries, such as silver and bio industries, that benefit from an aging population. Steel companies in countries with rapidly aging workforces can learn lessons from European and Japanese steelmakers that have already experienced this phenomenon.

The fates will be quite different for companies that are prepared for the silent but massive wave of demographic changes and those that are not.
Restructuring of the Chinese Steel Industry: Retrospects and Prospects

Frank Zhong
Chief Representative of Beijing Office
World Steel Association (worldsteel)

Over the past 35 years, the landscape of the global steel industry has changed dramatically owing to the rise of the Chinese steel industry, particularly over the past 15 years. As indicated in Figure 1, global steel demand in 2015 was 127.7% higher than in 1980, with a CAGR of 2.4%. However, without China, global steel demand would have grown by only 38.2%, with a CAGR of only 0.9% during the same period. China’s domestic steel demand in 2015 was 14.1 times higher than in 1980, with a CAGR of 8.3%. China’s steel demand growth accelerated significantly during the period from 2002 to 2013, with a much higher CAGR of 13.4%. As a result, China’s share in global steel demand expanded from 10.2% in 1980 to 46.7% in 2013.

However, statistics suggest that the change of the global steel landscape may have approached a watershed. On one hand, steel demand in some emerging economies, like India and the ASEAN, continues to grow robustly. On the other hand, a turning point in the growth of China’s steel demand has been observed, and more and more people believe that China’s steel demand may have already peaked in 2013. Industry analysts believe that in the long term it is unlikely that China’s steel demand will return to the 2013 level, given that the Chinese economy is shifting its growth driver from investment, which is highly steel intensive, to private consumption, which will require less steel for the same rate of growth.

Steel demand outside China is expected to remain stagnant because the global economy is still struggling to achieve stable growth. It is the consensus view that steel demand in developed economies is unlikely to return to the pre-crisis level recorded in 2007. The outlook is positive for some emerging economies, including India, the ASEAN, and MENA. There is no doubt that steel demand in these regions will continue to grow for decades due to strong demand in infrastructure construction and automobiles. However, steel demand in these regions is too
Restructuring of the Chinese Steel Industry: Retrospects and Prospects

In light of the domestic and external environment mentioned above, the Chinese steel industry has been squeezed drastically by excess supply. It is a big challenge for the Chinese steel industry to remain profitable and competitive, as steel demand is expected to decline, while excess capacity will not be immediately eliminated. It is high time for the steel industry to be restructured and re-organized to achieve sustainable development on economic, social and environmental fronts. The Chinese government and the steel industry have been aware of the challenge, and great efforts have been made in recent years. Nevertheless, more actions and measures are required, in particular from the government.

China’s steel policies in retrospect
The development of the Chinese steel industry, as well as the Chinese economy, has been largely policy-driven, and has benefited from continuous reform measures aimed at progressively incorporating market mechanisms into the centrally planned economy.

According to information available in the public domain, the Chinese government introduced more than 320 policies and measures from 1990 to 2016 (up to August 2016). About 49% of these policies and measures were issued by the central government, while the remaining 51% were issued by local governments. More than half of the 51% issued by local governments were following the actions of the central government, with more specific implementation arrangements for the specific regions. These policies and measures can be categorized into eight groups by subject: 5-year plans, guidance for general development,
Figure 2. Share of Government Policies and Measures by Subject

Figure 2 suggests that nearly half (49%) of the policies and measures introduced since 1990 were issued to control steel capacity expansion. This is an indication of how rapidly China’s steel capacity has been expanding and how difficult it has been for the government to rein in the increasing rate. The first capacity-related policy was introduced in the late 1990s. It simply provided guidance as to which types of facilities were not to be supported or built, and which types of facilities were encouraged. The last capacity-related policy, which was introduced by the State Council in early 2016 and is being followed by provincial authorities, provided a long list of steel companies and furnaces to be closed by the end of 2016. However, some industry observers doubt the potential effectiveness of the last policy, which calls for a 100-150 Mt capacity reduction by 2020, given that the steel market in 2016 was better than most people predicted, and the implementation of the policy remains a question mark for some regions. In addition to capacity control policies, policies regarding industry access also have a high share at 10%. To some extent, regulations on industry access were also intended to manage steel capacity expansion. In this sense, policies regarding capacity control represent almost 60% of all policies introduced since 1990.

Figure 3 demonstrates the change of focus of steel industry policies since 1990. Before 1990 there were not many policies specifically designed for the steel industry, and the main focuses were increasing the self-sufficiency of the steel supply by expanding domestic steel capacity, and improving the quality of domestically produced steel products. Capacity closure was first put into the government’s business agenda in the mid-1990s, when steel became abundant in China and China became world’s largest steel producing country. From that time on, closure of obsolete capacity became a constant item of almost all steel-related policies and measures. From 2003 onward, restriction of access to the steel industry was introduced to help eliminate illegal and unqualified steelmakers, but it was difficult to realize with existing regulations. After 2013, elimination of excess capacity became almost the only focus of policies and government actions, and the strengthening and implementation of environmental regulations has been the most effective tool in the capacity reduction campaign.

After almost 20 years of restructuring, the Chinese steel industry has improved dramatically in the area of technical and environmental performance, while its financial performance remains among the worst in the world. The long-standing issue of low industry concentration ratio is often regarded as one of the key drags on the industry’s
profitability. Figure 4 shows the change of the production share of the ten largest steel producers in China. When the “China Steel Industry Development Policy” was published in 2005, the target for the ten top producers’ share was 60% for 2015 and 70% for 2020. However, Figure 4 suggests that the concentration ratio has remained almost unchanged since 2005, though it picked up slightly in 2010, to 43%. In 2015, the ten top producers only represented 34% of the country’s crude steel production, which was far below the target set in 2005. In 2015, the updated “China Steel Industry Development Policy” reset the target for the top ten’s share to be the same number of 60%, but the time horizon for achieving this was extended to 2025. There is no alternative target for 2020.
As the Chinese economy is transforming from an investment-intensive development model to a more consumption-driven model, more and more people believe that China’s domestic steel demand may have reached its peak (or first peak) in 2013. During the “post-peak” years, the Chinese steel industry is facing various challenges, in particular overcapacity. “Restructuring” has been a frequently used keyword among people associated with the steel industry. However, people seem to have different views on how the Chinese steel industry could evolve in the post-peak period, and most people are not able to expose their views to the public. To better understand the different opinions on some important topics regarding the future of the Chinese steel industry, worldsteel organized a survey in July 2015 to

**Survey results on the future of the Chinese steel industry**

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collect independent views from people of diverse backgrounds around the world. The interviewees included economists, analysts, consultants, engineers, middle management, university professors, members of the media, etc.

The 17-question questionnaire was sent to a variety of interviewees around the world, and covered both people working in the steel industry and those outside the industry. All major steel producing and steel using regions were covered. In total, 311 useful feedback samples were received, and some additional remarks on a few questions were collected. According to the feedback, 59% of the respondents were between 25 and 45 years old, and 64% of them were Chinese. Respondents from steel producing companies accounted for 55%, and economists, analysts, and middle-top management, who are supposed to be knowledgeable about the steel industry, accounted for 60% of total respondents. Answers to some of the key questions are summarized below.

On the question “Do you think China’s domestic steel demand has peaked or not?”, a majority of 72.3% of respondents believed that China’s domestic steel demand already peaked in 2013 (see Figure 5). However, 16.9% of respondents did not think that China’s domestic steel demand has already peaked, but expect the peak to come very soon. And 6.2% of respondents (half non-Chinese) expect that it will take a long time before steel demand reaches its peak.

On the question “If Chinese demand peaked in 2013 (at 766 Mt, crude steel basis), at what level will Chinese steel demand eventually stabilize (say by 2030)?”, the views of respondents were divided (see Figure 6). About 2/3 of respondents expected a 10-20% decline, and of these, 26.7% expected steel demand to decrease by 20%. Some 19.6% (70% are Chinese) believed steel demand could go down by 25% or more.

On the question “Which support do you think is the most important for the government to provide in the process of restructuring?”, the consensus was that the government is expected to provide financial support (50.8%) and remove barriers to exit (49.2%). About 23.3% (60% are Chinese) requested that the government facilitate privat-
The feedback from the survey suggests that China’s domestic steel demand peaked in 2013, and will decline 10-20% before stabilizing. China has entered a post-peak era, but how the steel industry should be better restructured remains a question mark.

On the question “Which area do you think Chinese steel companies should improve the most in order to become globally competitive players?”, views were divided, but the answer “Business administration skills of top management” got the highest response (43.4%), followed by the answer “Operational technology, equipment” (27.9%) and “Improving environmental performance” (26.6%). Some respondents provided additional remarks that Chinese steel companies are already globally competitive.

On the question “If you know the history of restructuring in other countries, which model do you think the Chinese steel industry should follow?”, answers were extremely divided. About 20.4% of respondents said that they have no idea or knowledge to answer the question. Out of the remaining 79.6%, 31.3% believed the Japanese model is most suitable for the restructuring of the Chinese steel industry, and 16.4% thought the EU model is most appropriate. However, 26.6% of respondents chose the answer “None of the above (Japan, US, EU).” Additional remarks suggest that China will find its own way of restructuring its steel industry.

To summarize the findings, the feedback from the survey suggests that China’s domestic steel demand peaked in 2013, and will decline 10-20% before stabilizing. The government should lead the restructuring process, remove barriers to exit, provide financial support, and facilitate M&A’s and privatization of SOE’s. There is no clear view of which restructuring model China should follow from among the cases of Japan, the US and the EU. China has entered a post-peak era, but how the steel industry should be better restructured remains a question mark.

Suggestions for future restructuring

The Chinese steel industry is now at a critical turning point in its development, with “restructuring” being a high priority for sustainable development in the long term. The analysis
above suggests that the Chinese government, as well as the steel industry, has achieved much and made great progress in both economic and environmental areas in the past decades en route to a better-structured steel industry. However, the analysis also indicates that what has been done in the past may not have been sufficient, or that the measures in place have not been implemented in the way policy makers expected. In light of the new environment facing the Chinese steel industry, below are some suggestions for the Chinese government and the steel industry for the restructuring of the industry.

1. First and foremost, the government’s role should be gradually overtaken by market forces. 

The experience of the steel industry in developed economies (EU, US, Japan) suggests that there is a critical role for the government to play during the process of steel industry restructuring. Without any intervention by the government, restructuring would have gone nowhere, as industry players could hardly coordinate due to fierce competition immediately after the demand peak. It is also valid for the Chinese steel industry that the government should play a leading role in facilitating industry restructuring, as the industry is too fragmented to coordinate at the corporate level. However, the government should only play a leading role in the early stage of restructuring, providing financial support to help reduce excess capacity, resettling redundant employees, and reducing barriers to exit for loss-making companies. Once the barriers to exit are removed, it should be market forces that decide which steel producers remain in the market, rather than the government making a list of producers that are identified by certain criteria to be “qualified” to operate. This is even more important for industry consolidation. It should be the steelmakers who decide whether an M&A is commercially viable, rather than the

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**Figure 7. Shift of Power from Government to Market Force**

<table>
<thead>
<tr>
<th>1990s</th>
<th>2000s</th>
<th>2010s</th>
<th>2020s</th>
<th>2030s</th>
</tr>
</thead>
</table>

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In the longer term, the government, as the controlling shareholder of the steel companies, should guide the SOE’s in making a long-term business plan, and importantly, the plan should not just be politically right, but commercially viable.

government forcing mergers that it feels are workable. Figure 7 demonstrates how government influence should be replaced by the market forces in the future.

2. The steel industry should be consolidated to generate better synergy in the industry, in particular in market development and R&D.
A reasonably consolidated industrial structure enables the most players to allocate the best resources to improve the efficiency of the supply chain and R&D. The Chinese steel industry is currently too fragmented for producers to generate synergy. Survival is the top priority of nearly all producers, including those that used to be leading players in the market. But structural reorganization should be conducted in a proper way. Market forces or producers should be the decision maker on whether a merger proposal is commercially feasible or not. The government should not force any producer to merge, or stop any producer from being taken over by another. Cross-regional combination of producers usually brings better synergy and creates new market opportunities. Industry consolidation should be careful of the notion of “the bigger, the better, the stronger.” A bigger company means stronger bargaining power, but the value can be significantly offset by the huge costs of integration and inefficiency in operation management.

3. A joint fund should be initiated to support the restructuring.
In early 2016, the Chinese central government committed to devoting a total budget of RMB100 billion to deal with issues related to the capacity reduction campaign in the coal and steel industries. According to a statement from the government, the budget will be mainly assigned for resettlement of 1.3 million redundant employees in the coal industry and 0.5 million in the steel industry.
This budget is viewed as an excellent start that demonstrates the central government’s determination to help the industry address the core challenges of labor force treatment. It is expected that the provincial governments will come up with additional money to supplement the central government’s budget. However, the overall budget is rather limited compared to the magnitude of the capacity reduction and the resettling of redundant employees. An additional fund, which could be jointly established by the government and private sectors, could definitely fill the gap between the huge demand and the limited government budget. Such a public-private fund could help address not only employment issues, but also help resolve bad debts, facilitate M&A, and even be used in R&D initiatives.

4. Reform of state-owned steel enterprises (SOE’s) should be accelerated, the sooner the better.

The Chinese steel industry was dominated by state-owned steel companies for more than four decades, until the late 1990s, when private players started to emerge and grow rapidly. However, state-owned companies normally respond to changing market conditions at a slower pace, and the fast-growing private steel producers have taken over a large share of steel production. State-owned companies urgently need to reform the way they manage their businesses, as well as their people. In the longer term, the government, as the controlling shareholder of the steel companies, should guide the SOE’s in making a long-term business plan, and importantly, the plan should not just be politically right, but commercially viable.

5. Steel companies should be more integrated into the global steel industry.

Integration, both internally and externally, has become one of the most difficult problems of nearly all Chinese steel companies. Integration into the global steel industry does not only mean trading steel products and building facilities in other countries, but also having the openness to work with industry peers to share industry-wide responsibilities, impose influence on future industry development, and advocate for the image of the industry. The most critical determinant of successful integration is the mentality of the top management, in particular CEO’s. This means that CEO’s should be exposed to more global organizations and international events.

6. Steel companies’ human resources system should be more open.

In contrast to the industries in other steel producing regions, the human resources system of Chinese steel companies is quite closed, especially that of state-owned companies. Almost all Chinese steel companies recruit newly graduated students from universities every year to comply with the instructions of the government. It is very rare that Chinese steel companies recruit talent from the outside when there are vacant positions. Instead, they mostly recruit from inside the company to fill vacancies. The exception is that many private steel companies open their system to recruit both fresh graduates and mature talent from outside. This system makes it very difficult for Chinese steel companies, in particular state-owned companies, to attract young talent, especially internationally competitive specialists.
Myanmar, the Last Frontier in the ASEAN, Will See High Growth of its Steel Industry

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A new chapter opened in Myanmar in April 2016 when the country’s first non-military government in 54 years took office. As Aung San Suu Kyi’s National League for Democracy (NLD) won a landslide victory in the country’s parliamentary elections held in November 2015, Myanmar drew global attention. Even before the landmark elections, Myanmar has become a focus of global attention for its geopolitical and geo-economic importance since the Thein Sein administration, launched in 2011, pursued active reform and opening-up, followed by the lifting of economic sanctions against Myanmar by the EU in 2013 and the later easing of some U.S. sanctions.

Today, Myanmar is dubbed the “last frontier” in the ASEAN because of its high growth potential and high investment attractiveness as follows.

First, from the geopolitical perspective, Myanmar borders three important economic regions: China, India, and the ASEAN. Myanmar is China’s gateway to the Indian Ocean and India’s gateway to Southeast Asia. It is a strategic hub that connects massive consumer markets. For these reasons, Myanmar has high efficiency as a production base and high potential as a logistics base for these countries. Roads and ports directly linking mainland China and the Indian Ocean, the China-Myanmar-India Highway, and the Thailand-Myanmar-India Highway are under construction.

Second, Myanmar is a resource-rich country. Thanks to its complex geology, Myanmar has abundant natural resources: energy resources, including natural gas and oil; minerals, including copper, zinc, tin, tungsten, nickel, and lead; and gemstones, including rubies and sapphires. However, except for some natural gas and other resources, no mineral resources have been explored since the introduction of the Burmese Way to Socialism in the late 1960s. Myanmar, the so-called last bastion of natural resources, has much room for resources exploration.

Third, Myanmar has low labor costs and high quality labor, making it an ideal investment destination for labor-intensive industries. The average
Myanmar, the Last Frontier in the ASEAN, Will See High Growth of its Steel Industry

Myanmar’s monthly wage of factory workers in 2014 ranges from USD 90 to 110, which is lower than that of neighboring Southeast Asian countries, such as Vietnam and Indonesia. However, Myanmar’s labor productivity is quite high compared to its wages. According to a local sewing factory, Myanmar’s wages are half of Vietnam’s, but its labor productivity is about 80% of Vietnam’s. The ratio of labor productivity to wages in Myanmar is 1.6 times higher than that in Vietnam.

Finally, Myanmar has high potential as a domestic market. According to an IMF report in April 2016, Myanmar with a population of 51.48 million people (according to the census in May 2015) had a per capita GDP of USD 1,292 in 2015, and Yangon, the country’s largest city, had a per capita GDP of USD 1,700, surpassing the 1,000-dollar threshold that gives rise to the consumption of durable goods and a middle class. Notably, purchasing power per capita in Myanmar has increased at a greater rate than in Vietnam since 2011. It is projected to reach USD 5,953 in 2016 and USD 8,399 in 2020. In 2021, Myanmar’s purchasing power per capita is expected to reach USD 9,173, surpassing Vietnam’s USD 9,065.

Foreign direct investment (FDI) in Myanmar has continued to rise since it peaked in FY 2010 (April 1, 2010 to March 31, 2011) under reform and opening-up policies. In FY 2015,

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### Table 1. Myanmar’s Mineral Reserves

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Iron ore</th>
<th>Coal</th>
<th>Nickel</th>
<th>Zinc</th>
<th>Copper</th>
<th>Tungsten</th>
<th>Uranium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reserve</td>
<td>720</td>
<td>400</td>
<td>42</td>
<td>14</td>
<td>21</td>
<td>1</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Source: KORES, UNDP
### Table 2. Foreign Investment in Myanmar by Country and Industry (USD million)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>8,269</td>
<td>4,346</td>
<td>232</td>
<td>56</td>
<td>511</td>
<td>3,224</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>5,798</td>
<td>85</td>
<td>107</td>
<td>628</td>
<td>225</td>
<td></td>
</tr>
<tr>
<td>Korea</td>
<td>2,676</td>
<td>38</td>
<td>81</td>
<td>300</td>
<td>128</td>
<td></td>
</tr>
<tr>
<td>Thailand</td>
<td>2,146</td>
<td>1</td>
<td>529</td>
<td>166</td>
<td>238</td>
<td></td>
</tr>
<tr>
<td>Singapore</td>
<td>226</td>
<td>418</td>
<td>2,300</td>
<td>4,297</td>
<td>4,247</td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td>10</td>
<td>302</td>
<td>438</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>India</td>
<td>73</td>
<td>12</td>
<td>26</td>
<td>209</td>
<td>224</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>7</td>
<td>4</td>
<td>54</td>
<td>56</td>
<td>86</td>
<td>218</td>
</tr>
<tr>
<td>UK</td>
<td>799</td>
<td>100</td>
<td>233</td>
<td>157</td>
<td>857</td>
<td>75</td>
</tr>
</tbody>
</table>

Note: Statistics as of March 2016  
Source: Myanmar Investment Commission (MIC)

FDI in Myanmar grew by 8% year on year, to USD 9.5 billion. China’s FDI in Myanmar stood at USD 3.22 billion in FY 2015, and it had the lion’s share (USD 18.67 billion, 29.3%) of the accumulated investment amount (USD 63.72 billion) in the same year. China continues to increase investment this year. Singapore, in which the Asian headquarters of many global firms are located, has remained the top investor since FY 2012. The Netherlands, India, and other countries are also actively making inroads into Myanmar.

In the past, the oil and natural gas industry received the largest investment, but recently, investment has diversified into industries such as transportation and communication, real estate, and manufacturing (in particular, labor-intensive manufacturing, e.g. apparel and shoes). In FY 2015, the oil and natural gas industry received USD 4.82 billion of investment, transportation and communication USD 1.93 billion, manufacturing USD 1.07 billion, and real estate USD 729 million. These four industries account for more than 90% of total investment. FDI in power generation has decreased substantially, but it is expected to rise again due to rising demand for electricity following economic growth, and the development of manufacturing, transportation, and communication.

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**New government’s “people-friendly” and “infrastructure-oriented” economic policies**

The new administration has announced an economic blueprint, but no detail policies. However, during election campaigns, the ruling NLD party laid out policy directions under the slogan “Time for Change”: ▲ fiscal prudence, revitalizing agriculture and other industries closely linked to the livelihood of the people, ▲ stable supply of energy, ▲ improving the environment for foreign investors, ▲ refurbishing infrastructure, such as transportation, communication, and electricity, and ▲ improving the labor environment. Internally, the new administration will implement people-friendly policies, and externally, it will develop infrastructure through FDI and the support of international institutions.

These policy directions will provide foreign investors with various opportunities.

First, various reformative legislation, including the Foreign Investment Law, the Motor Vehicle Law, and the Central Bank of Myanmar...
With its growing geopolitical and geo-economic importance, and improved conditions for foreign investment, Myanmar is expected to maintain high economic growth until 2020.

Law, are expected to take effect within this year. As a result, barriers to investment, such as land lease and local hiring requirements, will be lowered. Greater independence for the Central Bank of Myanmar, and open financial policies, will increase transparency in the financial sector.

Second, new business opportunities will arise for medium-to-large infrastructure projects. Rather than one-off projects, demand for long-term large-scale projects will likely increase based on plans: ▲ Yangon New City Project, ▲ transportation, oil refining, mining, power transmission and distribution, and road construction projects, ▲ new opportunities for development of special economic zones.

Third, Myanmar is expected to receive more economic support and investment thanks to the US lifting economic sanctions. Myanmar companies and individuals are being taken off the sanction list, and will be provided with US loans and support. In particular, the generalized system of preference (GSP), the US trade preference program, will be applied on November 13, 2016, and dollar-denominated transactions will be possible as early as in 2016.

Lastly, the new administration considers lack of transparency in the government to be an obstacle to attracting foreign investment. Therefore, the new government is expected to be more transparent and fair in decision-making and policy implementation, for example in the allocation of business rights.

Meanwhile, “people-friendly” policies will put new pressures on companies. As the government has reduced the number of goods exempt from commercial taxes and increased public utility rates to boost state coffers for a better labor environment, companies may need more funds to enter Myanmar, and are highly likely to suffer from increased corporate taxes and income taxes. Moreover, wages are expected to rise due to some reformative measures in the labor environment, such as the introduction of a minimum wage, allowing workers to form unions, and improving labor standards. With the increased influence
of NGOs, there will be more lawsuits and delays in major infrastructure development projects, arising from conflicts involving compensation for land expropriation, relocation, and environmental issues.

### Highest growth rate in Southeast Asia

According to an IMF report released in 2016, Myanmar’s GDP growth rate was 8.5% in 2015, higher than that of China, India, and other ASEAN countries. Since former President Thein Sein adopted reform and opening-up policies to attract investment for economic growth, Myanmar has recorded high GDP growth rates, 7-9%, each year. With its growing geopolitical and geo-economic importance, and improved conditions for foreign investment, Myanmar is expected to maintain high economic growth until 2020.

**Fast growing steel demand in Myanmar, mainly for long products**

After Myanmar’s transition to a market economy in 1989, its finished steel consumption mainly for construction\(^1\), such as billets and steel bars, substantially increased, surpassing 500,000 tonnes in 2000. Steel consumption declined as the economy slowed following the strengthening of U.S. economic sanctions in 2003, but began to demonstrate an upward trend after steel consumption overtook its previous peak in the late 2000s thanks to a prosperous construction market backed by increased natural gas production. In addition, foreign investment inflows following reform and opening-up policies in 2011 have contributed to the upsurge in steel demand.

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Due to insufficient statistics on Myanmar’s steel industry, this figure was estimated based on market research by Myanmar-POSCO and POSCO Research Institute.
Myanmar’s finished steel demand was 1.62 Mt in 2014, showing a CAGR of 13.4% after 2003. Without a solid foundation of steel-consuming industries, such as automotive, home appliance, and shipbuilding, demand for long products and galvanized and color-coated sheet used for construction is 1.09 Mt (68%) and 0.3 Mt (19%), respectively, accounting for nearly 90% of total steel demand.

Among flat products, demand for galvanized and color-coated sheet is surging. Demand for galvanized sheet has risen 30% each year for the last five years, reaching 200,000 tonnes in 2014. Since reform and opening-up, demand for residential roofing materials has increased, and recently, demand for commercial construction materials has surged. Demand for color-coated sheet reached about 100,000 tonnes in 2014. Its use in factory exteriors and roofing, and in roofing for middle-to-upper class homes in cities, is rising.

In the meantime, the hot-rolled sheet and plate market remains at only 200,000 tonnes.

**Table 3. Supply and Demand by Product, 2014**

<table>
<thead>
<tr>
<th></th>
<th>Long products</th>
<th>HR/Plate</th>
<th>CR (Full Hard)</th>
<th>GI</th>
<th>Color</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total demand</td>
<td>1,090</td>
<td>200</td>
<td>24</td>
<td>198</td>
<td>103</td>
<td>1,615</td>
</tr>
<tr>
<td>Domestic production</td>
<td>110</td>
<td>20</td>
<td>-</td>
<td>23</td>
<td>-</td>
<td>153</td>
</tr>
<tr>
<td>Imports</td>
<td>980</td>
<td>180</td>
<td>24</td>
<td>175</td>
<td>103</td>
<td>1,462</td>
</tr>
<tr>
<td>Share of imports (%)</td>
<td>89.9</td>
<td>90.0</td>
<td>100</td>
<td>88.4</td>
<td>100</td>
<td>90.5</td>
</tr>
</tbody>
</table>

Note: MPCC, the first color-coated sheet manufacturer in Myanmar, began operation in November 2014.
Source: Myanmar POSCO, POSCO Research Institute
There is no cold-rolled sheet market in Myanmar as it imports only full hard used for galvanized sheet.

Due to poor competitiveness in steel production, caused by power shortages, substandard operational skills, and inadequate facility management, finished steel production was only 153,000 tonnes in 2014, out of a capacity of 650,000 tonnes (including suspended facilities). This translates to a capacity utilization rate of just above 20%.

With the import market wide open after reform and opening-up policies, Myanmar’s import duty rate is only 1%. Increasing demand for steel is mostly satisfied by imports. The share of imports rose continuously from 85% in 2011 to 91% in 2014.

In Myanmar, there are currently five state-owned steel mills: two steel mills under the Ministry of Industry (No. 4 and No.5) and three steel mills (No.1 - No.3) under Myanmar Economic Cooperation (MEC), a state-owned company that is part of the Ministry of Defense. There are also three galvanized steelmakers and one color-coated sheet manufacturer.

The five state-owned mills are called No.1 through No.5, mainly based on size. In the past, MEC operated all state-owned mills. Because No.4 and No.5 had low operation rates and over-spending of investment funds placed a financial burden on the Ministry of Defense, their operator was changed from the Ministry of Defense to the Ministry of Industry in late 2012. The Ministry of Industry is investing in the No.4 mill to expand its capacity from 200,000 tonnes to 400,000 tonnes, making it the largest steel plant in Myanmar. However, due to poor construction management and insufficient funds, construction has been delayed for over two years. Completion is projected for 2018, but further delays are likely. The No.5 steel mill with a pig iron capacity of 200,000 tonnes is located on Mount Pinpet, which has iron ore deposits. Its operation is currently suspended.

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**Myanmar’s five state-owned mills and four private mills**

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**Table 4. Status and Location of Myanmar’s State-owned Mills**

<table>
<thead>
<tr>
<th>Business operator</th>
<th>NO.1</th>
<th>NO.2</th>
<th>NO.3</th>
<th>NO.4</th>
<th>NO.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Pyaye</td>
<td>Myaungdagar (Yangon)</td>
<td>Insein (Yangon)</td>
<td>Myingyan</td>
<td>Pinpet</td>
</tr>
<tr>
<td>Supplier</td>
<td>Danieli (Italy)</td>
<td>NKK (Japan)</td>
<td>DEMAG (Germany)</td>
<td>Danieli (Italy)</td>
<td>Russia</td>
</tr>
<tr>
<td>Capacity (1,000 tonnes)</td>
<td>Bar &amp; wire: 200</td>
<td>Plate: 150</td>
<td>Billet &amp; wire: 40</td>
<td>Slab &amp; billet: 200</td>
<td>Pig Iron: 200</td>
</tr>
<tr>
<td>Production 2014 (1,000 tonnes)</td>
<td>Bar: 100</td>
<td>Plate: 20</td>
<td>-</td>
<td>Billet: 20 ~ 30</td>
<td>Suspended</td>
</tr>
</tbody>
</table>

Source: Myanmar POSCO, POSCO Research Institute
Three galvanized sheet manufacturers—MPSC, MEC, and Mega Steel—are currently in operation in Myanmar. After 1997, six manufacturers were established (four Japanese, one Korean, and one Myanmar). However, due to the government’s unreasonable restrictions and a deteriorating business environment, three Japanese companies either left Myanmar, or was acquired by MEC, or sold its stake. The Myanmar company, Myanmar Steel Ltd., gave up production amidst fierce competition and became a trader. The remaining three mills are witnessing their sales decline amid heavy inflows of Chinese imports. There is only one color-coated sheet manufacturer in Myanmar: Korea’s MPCC with began operation in December 2014, producing color-coated sheet used for industrial buildings.

Myanmar’s steel consumption is estimated to be over 2.1 Mt in 2015, and it is expected to grow around 8%, surpassing 3 Mt for the first time in 2020, and reaching 5 Mt in 2025.

This figure is assumed steel consumption in Myanmar based on a model of panel data on steel consumption and per capita income (1991-2010) in five Southeast Asian countries.

Table 5. Galvanized and Color-coated Sheet Manufacturers in Myanmar

<table>
<thead>
<tr>
<th></th>
<th>MEGA Steel</th>
<th>MEC</th>
<th>MPSC</th>
<th>MPCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product</td>
<td>GI</td>
<td>Color</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td></td>
<td>Yangon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major shareholder</td>
<td>Mega Group (Singapore)</td>
<td>Myanmar</td>
<td>POSCO+MEHL</td>
<td>POSCO + MEHL</td>
</tr>
<tr>
<td>CAPA/y</td>
<td>30,000 tonnes</td>
<td>24,000 tonnes</td>
<td>30,000 tonnes</td>
<td>50,000 tonnes</td>
</tr>
</tbody>
</table>

Source: Myanmar POSCO, POSCO Research Institute

Figure 4. Myanmar’s Finished Steel Consumption and Per Capita Consumption Forecast

Source: POSCO Research Institute
Demand for long products and flat products for construction is projected to lead the market because Myanmar’s economic development will be centered on infrastructure, construction, and light industries in the short-to-mid term.

Per capita steel consumption is also expected to increase, from 41kg in 2015 to nearly 60kg in 2020, and over 80kg in 2025.

Demand for long products and flat products for construction is projected to lead the market because Myanmar’s economic development will be centered on infrastructure, construction, and light industries in the short-to-mid term.

Amidst increasing steel demand, the foremost challenges for Myanmar’s steel industry are building a stable production system for state-owned steel mills and increasing capacity to defend against imports. Most importantly, it is necessary to normalize the operation of the Myingyan steel plant (No. 4 steel plant), which is a small-scale upstream producer, but the only slab and billet maker in Myanmar. The Myingyan steel plant has an operation rate of just above 10%, due to troubled facilities that hinder production, aggravated by logistics troubles caused by the long distance between the steel plant and Pinpet iron mine (over 200 kilometers away) and its market, Yangon (over 500 kilometers away). To make matters worse, investments were made after 2010 in facilities for downstream production, including electric arc furnaces, hot-rolled, cold-rolled, galvanized, and long products, but poor management of investments delayed operations. In order to get on track, the Myingyan steel plant needs to build a logistics network between the Pinpet mine and Yangon, effectively manage facilities with support from equipment suppliers, and ensure transparency in the management of investment projects. Re-location nearer to Yangon and new investment would be plausible alternatives.

Myanmar’s steel industry is greatly affected by the overcapacity of steel powerhouse China. Even in the local mill-dominated galvanized sheet market, local mills are losing market share to cheap Chinese products. For further growth, Myanmar’s steel industry needs to
revamp management and receive active government support until they gain competitiveness.

Myanmar was only a least developed country recently, and it has limited markets compared to Vietnam and other neighboring countries. For example, in the galvanized sheet market, according to market surveys conducted in 2011 and 2012 by POSCO Research Institute, Myanmar had feeble demand for channels, sandwich panels, and guardrails, which are made from galvanized sheets, and some traders did not even know about such products. However, a recent survey in 2015 shows that there is an increasing number of channel processing companies in Myanmar. After only several years, Myanmar is witnessing the rapid growth of markets that never existed before. Under these circumstances, Myanmar needs to seek marketing strategies to target new markets, considering the growth trajectory of neighboring countries, and build new business models to ensure the sustainability of local steel mills.

Success Case of Myanmar POSCO Steel Co., Ltd. (MPSC)

Myanmar POSCO Steel Co., Ltd. (MPSC) is a rolling mill with an annual capacity of 30,000 tonnes of galvanized sheet for roofing, and a joint venture established in 1997 (POSCO 70%, MEHL 30%). At that time, four Japanese companies occupied the market, but MPSC ventured into every corner of the country to find new markets. In 2000, only two years after beginning operation, MPSC recorded net profits.

However, cheap smuggled goods began pouring into Myanmar after 2004, and regulations on thickness became unreasonably strict in 2005. Most local steel producers in Myanmar reduced or stopped operations. MPSC also shut down operations for over a year. Smuggled goods occupied the market.

MPSC, together with its partner, engaged in active government relations until the government finally removed the unfair regulations in 2006. After operations resumed, MPSC improved product quality and adopted premium marketing strategies. Thanks to the success of TV commercials, its product, Super Star, was established as a premium brand. Within only 2-3 months after the TV commercials aired, MPSC overwhelmed its rivals in terms of orders and pricing. Its market share grew rapidly each year (10% → 15% → 25%), and its selling price is 5-20% higher than that of its competitors. Moreover, with its diligent tax payment (20th largest taxpayer in FY 2010), MPSC is regarded as an exemplary foreign company by the Myanmar government. Through various corporate social responsibility (CSR) activities, MPSC has cultivated a positive company image. The company still maintains a higher market share and price point than its rivals. As the 20-year joint venture ends in 2017 (extendible twice, for five years each), MPSC is seeking various measures to respond to Chinese imports and make new investments to produce high-quality products in Myanmar.
EXAMINING THE PAST 100 YEARS
WHERE IS THE STEEL SUPER CYCLE HEADED?

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Looking at long-run data of real steel prices over the last 100 years, high volatility in steel prices is not just a recent phenomenon. Steel prices had high volatility from a long time ago and repeated long-run cycles with ups and downs. Real steel prices had long downswings for about 25 years after the first oil shock in the early 1970s, and surged sharply in the 2000s. After a decline in 2010, steel prices began rising in 2016. Then where will steel prices go?

This article assumes that steel prices repeat long-run cycles throughout a long-run trend. If the long-run trend, long-run cycle, short-run cycle can be decomposed from steel price data, it would be helpful to verify this argument and forecast steel prices.

In the 2000s, many experts recognized the existence of long-run cycles with upswings lasting from 10 to 35 years, and termed such cycle as a super cycle. In addition, with the development of a “band-pass filter,” it became possible to decompose a long-run trend, super cycle, and short-run cycle from real data. In this article, this concept of a super cycle and the band-pass filter are applied to steel prices, giving important insight into the directions of steel prices.

This article analyzed US real HR price from 1900 to 2016, which for the first time included the latest data until 2016 unlike any other past studies on super cycles. According to this analysis, it turns out that the long-run trend peaked in the early 1970s and declined afterward. The super cycle, which is in its fourth cycle, peaked in 2011 and entered a downward phase. Decomposition of real steel prices suggests four super cycles (1928~1949, 1950~1972, 1973~1996, 1997~). The current fourth super cycle is attributed to rising steel demand driven by China’s industrialization and urbanization (China effect) and supply lagging behind the sudden upsurge in demand. Being too optimistic about the prolonged upswings of the super cycle, the global steel industry made excessive investment in facilities. The fourth super cycle failed to maintain an upturn and turned downward prematurely. In the meantime, super cycles of other commodities, including iron ore, crude oil, copper, and aluminum, are quite similar to steel super cycles after 2000, because they share the same cause of a super cycle, the “China effect.”

Amid a prolonged low growth of the steel industry, the critical factor to shorten the super downtrend and downcycle is how fast excessive capacity can be reduced. It is also important how fast the economic growth of emerging markets, especially India and the ASEAN, will offset a steel demand slowdown in China.

Although the long-run trend and super cycles are in the downward phase, short-run business cycles have been volatile recently. This will continue for a while. Therefore, steelmakers should pay close attention to short-term business cycles rather than long-run cycles to keep cash flow steady and maximize profits.

**Executive Summary**

![Figure 1. Trend-Cycle Decomposition of Real Steel Price](image)

Note: Long-run cycle is extracted by specifying period of 20-70 years using a band-pass filter
Source: USGS, CRU, POSCO Research Institute
Amid the high volatility of steel prices in the 2000s, the global steel industry began facing mounting uncertainty. Many people think that steel prices had been quite stable and began to fluctuate only in the last 15 years. By nominal price, this misapprehension might seem correct. But looking at real prices over the last 100 years, it turns out that steel prices have had high volatility for a long time, and they repeat long-run cycles of ups and downs. (See Figure 2)

According to long-run data of US real HR prices, steel prices had a long downturn of about 25 years after the first oil shock in the early 1970s, and surged sharply in the 2000s. Then, steel prices fell again after 2010. Current prices remain below the lowest prices before the 1950s. In 2016, steel prices began rising, but no one knows for sure where steel prices will go.

There are mixed views on the recent movement of steel prices. Some might argue that the steel price decline in the last few years is an extension of the current long-run downward trend, while others might claim that the price decline is only a temporary phenomenon of the short-run business cycle and steel prices will recover in the medium- to long-run. Perhaps, an economist might seek a compromise explanation that steel prices are falling in the long-run trend, but have bounced back from the bottom from the perspective of medium- to long-run cycles.

What is a super cycle?

Since Citigroup analyst Alan Heap released a report titled “China: The Engine of a Commodities Super Cycle” in 2005, the term “super cycle” has become popular around the world. Heap defined a super cycle as a “prolonged (decades-long) trend rise in real commodity prices driven by urbanization and industrialization of a major economy.” As shown by this definition, early research on super cycles focused only on

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prolonged rises of commodity prices, with little analysis of actual cyclical movement. Even Mr. Heap did not use a strict methodology to extract super cycles from commodity price data. Nor did he define the frequency of super cycles.

The empirical research on super cycles began in earnest when a band-pass filter was used for long-run commodity price data. The band-pass filter is able to extract cycles of different frequencies of short-, medium- and long-run cyclical movement from economic time series, as suggested by Baxter and King (1999) and Christiano and Fitzgerald (2003). With the introduction of band-pass filters, many economists were able to extract super cycle components from a commodity price time series.

Cuddington and Jerrett (2008) defined the long-run trend as all cyclical components with periods in excess of 70 years, and assumed that super cycles have upswings of 10 to 35 years, taking 20-70 years to generate a complete cycle. The long-run steel prices are decomposed into the following three components:

\[
\text{Long-run price} = \text{① Long-run (super) trend (period over 70 years)} + \text{② Super cycle (20-70 years)} + \text{③ Business cycle (2-20 years)}
\]

In time series analysis, many filtering methods are used to decompose trends and the cyclical components of a time series by specifying a range of frequencies. A filter is a device that passes frequencies within a certain range and rejects frequencies outside that range. By range of frequencies, filters are classified into three categories; low-pass filter, high-pass filter, and band-pass filter. A low-pass filter removes high frequency cycles while retaining only slow-moving components of the data. By contrast, a high-pass filter eliminates very slow moving components...
With this decomposition, we assume that the long-run trend is not constant, but rather evolves very slowly over time. Deviation from the long-run trend and super cycle is considered a short- to mid-term business cycle component. The sum of the three components equals the long-run price.

### Steel price super cycles over the last 100 years

We used the asymmetric Christiano-Fitzgerald band-pass filter to extract a long-run trend and super cycles from long-term US real HR price series (1900-2016). Let’s take a look at the long-run (super) trend of steel prices. For this, we used a band-pass filter to extract cyclical components with periods over 70 years.

As shown in Figure 3, the long-run trend of the real steel price shows a downturn after a peak in the early 1970s, (i.e., trend) and retains high-frequency components. The Hodrick-Prescott filter widely used in economics is a high-pass filter, and is unable to extract long-run cycles with lower frequencies.

A band-pass filter lets certain ranges of frequencies pass through, while filtering out higher and lower frequency components. Using a band-pass filter, one is able to extract cycles of different periodicities (short-, medium-, long-run) by setting lower and upper bounds. There are two types of band-pass filter: symmetric and asymmetric. Baxter and King (1999) designed a symmetric filter, while Christiano and Fitzgerald (2003) developed an asymmetric filter. The advantage of an asymmetric filter is that there is no loss of a number of observations at the beginning and end of a data sample.

Band-pass filters have been widely used for extraction of long-run commodity price cycles since the 2000s. Jerrett and Cuddington (2008) were the first to use the asymmetric Christiano-Fitzgerald band-pass filter for steel price analysis. Following their lead, we employ the asymmetric Christiano-Fitzgerald band-pass filter to decompose the real steel price.

The real steel price (RP) can be decomposed into three components: (1) long-run trend (RP_T), (2) super cycle (RP_SC), and (3) other shorter cyclical components (RP_O). A super cycle is assumed to last 20 to 70 years.

\[
RP_T + \text{RP}_{SC} + \text{RP}_O
\]

Examination of Steel Super Cycles

<table>
<thead>
<tr>
<th>Start</th>
<th>Peak</th>
<th>Trough</th>
<th>Year to peak</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1928</td>
<td>1939</td>
<td>1949</td>
<td>12</td>
<td>22</td>
</tr>
<tr>
<td>1950</td>
<td>1963</td>
<td>1972</td>
<td>14</td>
<td>23</td>
</tr>
<tr>
<td>1987</td>
<td>2011</td>
<td>?</td>
<td>15</td>
<td>?</td>
</tr>
</tbody>
</table>

Band-pass filters have been widely used for extraction of long-run commodity price cycles since the 2000s. Jerrett and Cuddington (2008) were the first to use the asymmetric Christiano-Fitzgerald band-pass filter for steel price analysis. Following their lead, we employ the asymmetric Christiano-Fitzgerald band-pass filter to decompose the real steel price.

The real steel price (RP) can be decomposed into three components: (1) long-run trend (RP_T), (2) super cycle (RP_SC), and (3) other shorter cyclical components (RP_O). A super cycle is assumed to last 20 to 70 years.

\[
RP = \text{RP}_T + \text{RP}_{SC} + \text{RP}_O
\]

\[
= \text{RP}_{BP(70, \infty)} + \text{RP}_{BP(20, 70)} + \text{RP}_{BP(2, 20)}
\]

* BP(20, 70) denotes a band-pass filter with band (20, 70)
and the real steel price repeats a decade-long fluctuation throughout the long-run trend. However, with this graph alone, it is not easy to judge whether the long-run trend has already hit bottom or will continue to fall. Therefore, in order to more precisely predict the future direction of the real steel price, it is necessary to see the super cycle moving along with the long-run trend.

From the detrended real steel prices (difference between actual price data and the long-run trend), we can extract super cycles with a period of 20-70 years by using a band-pass filter. The super cycles of the detrended real steel prices are shown in Figure 4.

There is strong evidence of super cycles in the real steel prices. The length of a steel price super cycle is about 20-25 years, similar to many other commodity super cycles as shown later. The upward phase of past steel price super cycles lasted for 10-15 years. Decomposition of the real steel prices suggests that there were four long upcycle periods from 1900 to 2016 (1928-1939, 1950-1963, 1973-1981, 1997-2011). (see Figure 4 and Table 1).

Our results show that the current steel price super cycle is the fourth over the past 100 years, after peaking in 2011. The results are not sufficient to determine when the fourth super cycle will hit bottom, but there is a strong possibility that the downcycle will continue for the next several years.

How does a super cycle begin?

In order to forecast the direction of a super cycle, it is important to identify which mechanism past super cycles are generated from. Alan Heap (2005) argued that commodity super cycles are demand-driven, and highly materials-intensive economic activity is the cause of super cycles. However, commodity prices are decided by the demand-supply equilibrium. For this reason, emphasizing only demand side factors can lead to the misjudgment of a super cycle. In keeping with Cuddington and Jerrett (2009), there are three conditions necessary for the occurrence of a super cycle:

1. Continuous high demand: Past super cycles were driven by exponential increases in demand (e.g., US economic growth in the early 1900s, around World War II (1940s), post-war reconstruction after 1950s)
2. Short-term supply constraints: Short-term supply shortages trigger price increases (A short-term demand surge in steel and non-ferrous metals is very likely to cause supply shortages.)
3. Slow capacity adjustment in response to demand, driving continuous price increase (The speed of long-run supply response is critical for sustained demand expansion to give rise to a super cycle. In the steel industry, capacity expansion lags behind surging demand.)

The global steel market in the 2000s satisfied the three conditions to see another super cycle. First, steel demand in China grew explosively following industrialization and urbanization in the 2000s. Second, the sudden disruption in raw materials supplies caused by natural disasters in 2005 and 2008 constrained steel production in the short term. Third, new capacity increased only slightly until the early 2000s. Considering the demand rise in China, the supply glut was smaller than expected in the early 2000s. After the global financial crisis, China’s overcapacity emerged as a serious issue in the global steel industry. Clearly, steel prices in the fourth super cycle, which is still underway, are affected primarily by the ups and downs of the so-called “China effect.”

Co-movement with other commodity super cycles

How does the steel price super cycle differ from other commodity super cycles? To answer this question, we extracted super cycles of iron ore, which is most relevant to steel, and other commodities, including crude oil, copper, and aluminum, using the same band-pass filter.

As shown in Figure 6, other commodity super cycles are quite similar to steel super cycles after 2000, because they share the same cause, the “China effect.”

In particular, the super cycles of iron ore price, which has high correlation to steel price, have moved in sync with steel price super cycles. Real iron ore price is highly likely to stand at pre-1970s levels. The iron ore super cycle recently entered a downward phase after 2013. However, despite its gradual fall, the long-run trend of iron ore price remains relatively high, unlike that of steel price as shown in Figure 1.

Although the super cycles of steel price and other commodity prices have moved in close correlation, there is no guarantee that this pattern will continue, because the steel industry has characteristics that are distinct from other commodity industries. In the case of other commodities, the downturn of a super cycle is caused primarily by technological advancement and an increase in new supply following high prices. One example is shale gas. In contrast, steel (iron) has vast reserves and a high recycling rate compared to other commodities. Therefore, it is practically free from resource constraints. Moreover, due to overcapacity, steel supply can be expanded at any time without technological advancement. For these reasons, one should not rule out the possibility that the steel price super cycle will have a different pattern from other commodity price super cycles.

Factors that influenced steel price super cycles
Although most commodity price super cycles, including steel, turned downward around 2010-2012, the debate over commodity price super cycles is still going on.\(^6\)

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Some people may mistakenly conclude that the current downcycle is ending and another price boom is coming. On the contrary, it is time to worry about an ongoing super downcycle. As seen in Table 2, the supply and demand side factors in the global steel market will determine the length and amplitude of the downcycle in the future.

Ironically, the most important determinant of the current super downcycle might be the previous super upcycle. Since Alan Heap (2005), many super cycle believers have extensively discussed the China boom and super cycles, leading to the spread of the term “super cycle.” In the 2000s, the “bandwagon effect” led to excessive investment in the steel industry, resulting in overcapacity.

Figure 8 and Figure 9 give some evidence to support our argument. During the period of the super upcycle in the early-to-mid 2000s, steelmakers’ capital outlay and crude steel capacity surged dramatically, which is presumed to have influenced the downturn of the super cycle thereafter. This finding points to the possibility that supply side factors are more

---

**Table 2. Causes of Steel Price Super Cycle in the 2000s**

<table>
<thead>
<tr>
<th></th>
<th>2000-2011 (Upcycle)</th>
<th>2012- (Downcycle)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demand</strong></td>
<td>• Surging steel demand following industrialization and urbanization in China</td>
<td>• Steel demand growth turns negative as China’s economic growth slows</td>
</tr>
<tr>
<td></td>
<td>• High demand in non-China BRICs nations</td>
<td>• Demand of emerging countries (India, MENA, Southeast Asia) is anticipated to grow but is not expected to take off before 2020</td>
</tr>
<tr>
<td><strong>Supply</strong></td>
<td>• Short-term supply disruption of iron ore, cokes, and other raw materials due to natural disasters</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Despite overcapacity in China, obsolete facilities in advanced countries limit capacity expansion</td>
<td>• Global-level discussion just started to address overcapacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• China’s “supply-side reform” is anticipated to progress, but it will take time and energy to implement policies</td>
</tr>
</tbody>
</table>
important than demand side factors to reverse a steel price super cycle.

If the current super downcycle is likely to continue for a while, steelmakers might need to pay more attention to short-run business cycles than to the long-run trend or super cycle. Having identified the long-run trend and the steel price super cycle, they should now focus on the shorter business cycles.

Figure 8. Steel Super Cycle vs. Steel Investment

Note: Capital outlay is calculated by investment per ton of shipment (3-month moving average)
Source: WSD, POSCO Research Institute

Figure 9. Steel Super Cycle vs. Capacity Change

Note: Crude steel capacity change is based on a 3-month moving average
Source: OECD, POSCO Research Institute

Short steel business cycles since the second oil shock

So far, we have analyzed the movement of steel prices over the last 100 years by decomposing the long-run trend and the long-run cyclical components. Now we will analyze the movement of short steel business cycles after 1980. Deviations between actual prices and super cycles are interpreted as the shorter cyclical components that we call “business cycle.” To increase the accuracy of frequency and amplitude of shorter cycles, monthly US domestic HR prices after 1980 were used instead of yearly data. Business cycles are extracted by specifying a period of 8-40 quarters using a band-pass filter. (Yearly data would have produced similar results to monthly data, but with less accuracy of short-term frequency and amplitude.)

Examination of variations in steel price business cycles from 1980 shows that US real HR price, from the perspective of short-run cycle, may have hit the bottom of the 8th cycle after 2014. According to Figure 10, the length of business cycles became shorter and the amplitude increased around the global financial crisis. This price volatility may be attributed to a demand surge in China in the 2000s, price plunge during the crisis in 2008-09, stimulus packages to overcome the crisis, and chronic demand deficiency amid a prolonged economic slowdown. In particular, the difference between the highest and lowest prices of the 5th and 6th cycles is USD 300/ton, showing roller-coaster-like price volatility.

Where is the steel price cycle headed?

After we have examined the movement of steel cycles over the last 100 years, it is natural to wonder how long-run cycles and short-run business cycles will unfold. As Gangelhoff (2015) said, “the turning points in a super-cycle are a matter of judgment and are only apparent ex post,” it is extremely difficult to forecast the future, especially in the

middle of an ongoing super cycle.

With great uncertainty about the future, we could posit three or four scenarios. However, we intend to close this article by sketching a predictable future for steel price cycles based on the movement of steel and iron ore price cycles over the last 100 years. Repeating cycles in the past can better predict future cycles than scenario analysis, and provide lessons and implications for the global steel community.

In terms of long-run cycles, assuming an extension of the graph of long-run super trend and cycle decomposition in Figure 1, cycles lasting over the next 10 to 15 years are highly likely to have similar patterns to Figure 11.

In terms of the super trend, questions remain whether the downtrend will continue or an uptrend will begin within a few years. Taking into account of global overcapacity, post-peak controversy in China, and delayed growth in emerging markets after the financial crisis, the argument that the low price trend will continue is gaining ground. Amidst the prolonged low growth of the global steel industry in the next decade, long-run marginal cost of iron ore may also see a downward trend, owing to the continuous increase of iron ore supply and abundant scrap generation especially in China.

The recent super downcycle reflects the price decline after 2010, and may suggest further decline from the per-

### Figure 10. Short-term Business Cycles of US Real HR Price

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Points of cyclical change</th>
<th>Length (Months)</th>
<th>Amplitude (USD/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Peak</td>
<td>Trough</td>
<td>Peak</td>
</tr>
<tr>
<td>1st</td>
<td>'81.7</td>
<td>'86.1</td>
<td>'88.1</td>
</tr>
<tr>
<td>2nd</td>
<td>'88.1</td>
<td>'90.1</td>
<td>'94.5</td>
</tr>
<tr>
<td>3rd</td>
<td>'94.5</td>
<td>'96.1</td>
<td>'99.12</td>
</tr>
<tr>
<td>4th</td>
<td>'99.12</td>
<td>'03.2</td>
<td>'05.1</td>
</tr>
<tr>
<td>5th</td>
<td>'05.1</td>
<td>'06.10</td>
<td>'08.5</td>
</tr>
<tr>
<td>6th</td>
<td>'08.5</td>
<td>'09.11</td>
<td>'11.6</td>
</tr>
<tr>
<td>7th</td>
<td>'11.6</td>
<td>'12.11</td>
<td>'14.2</td>
</tr>
<tr>
<td>8th</td>
<td>'14.2</td>
<td>'15.9</td>
<td>-</td>
</tr>
</tbody>
</table>

**Note**: Real Price is monthly US domestic HR price discounted by US CPI (2015=100). A business cycle is extracted by specifying a period of 8-40 quarters using a band-pass filter.

**Source**: CRU, POSCO Research Institute
The critical factor to shortening the super downtrend and downcycle is how fast excessive capacity can be reduced in the next five to ten years. It is also important how fast the economic growth of emerging markets, especially India and the ASEAN, will offset the steel demand slowdown in China.

Short-run business cycles have demonstrated high volatility in recent years, and this volatility may last for a considerable time. As shown in Figure 12, the amplitude of short-run upcycles and downcycles will be determined by facility reduction announcement and consolidation policies in major steel-producing countries such as China. Short-run cycles also depend on the sustainability of China’s growth and the recovery speed of emerging markets.

Therefore, even in the overall downtrend, short-run business cycles will show volatility, which will surely have a massive impact on steelmakers’ strategic decision-making. For this reason, the steel industry should pay close attention to short-run business cycles in order to keep cash flows maintained. Precise forecasting and insight into short-run cycles are necessary to maximize short-run profits in the downcycle.
The global steel export market is riding a wave of change in the face of surprisingly high growth in the Chinese steel industry. Japan used to be the world's top steel exporting country, but it was overtaken by China in 2006. Other major steel exporting countries, including Russia, Germany, and Ukraine, are continuously losing ground. While China has poured massive amounts of steel products into overseas markets for a couple of years in order to overcome sluggish domestic demand and oversupply, Korea, Japan, and other steel exporting countries have been threatened by worsening profitability of their major steelmakers caused by China's encroachment into the global steel market, and plunging steel prices. With competition for steel exports becoming fierce and the center of the global steel structure shifting to China, major global steel mills are focusing on trade markets. Therefore, it is all the more necessary to take a long look at the landscape of the steel exports strategies of Korea, China, and Japan—a key factor of change in the global trade market—and to determine whether changes to the trade market landscape will be sustainable.

Korea, China, and Japan, the world’s top three steel exporters

Following the rise of China, the global steel trade market entered a period of structural transition in the 2000s. China used to be a net importer of steel and a “key market” for global steelmakers. However, as its steel production has
increased through the expansion of infrastructure and the explosive growth of steel-consuming industries such as automotive and home appliances, China has become a net steel exporter. In 2006, China overtook traditional export powerhouses, including Japan, Russia, and Germany, to become the world’s largest steel exporting country, and has remained the uncontested No. 1 since 2011. China’s share in the global steel trade market was a mere 1.4% in 2000, but rapidly increased to 10.3% in 2006 and 24.1% in 2015. Meanwhile, Korea solidified its footing as one of the world’s top 10 steel exporters in the 2000s. After beginning massive investments in overseas downstream facilities in 2011, Korea rose to be the world’s third largest steel exporter, taking advantage of the lackluster steel industries of Germany, Russia, and France during the financial crisis. Although Japan has been relegated to second place by China, it still shows prowess as an export powerhouse. As the world’s top three steel exporters, Korea, China, and Japan are front-runners in the structural change of the steel export market. The three countries’ exports stood at 183.6 Mt in 2015, accounting for 39.7% of global steel trade. They are still expanding into the global market with differentiated export strategies in order to increase their shares.

**China diversifies export items and destinations**

China has entered a “new normal” era, with its economic growth rate slowing to below 7% and infrastructure investment diminishing. The real estate market lost vitality, and the growth of steel-consuming industries, such as automotive and home appliances, is far below past levels. Under these circumstances, steel consumption fell 5.4% in 2015. However, steel production has grown at a CAGR of 15.4% since 2000, reaching peak overcapacity. The imbalance of supply and demand imbalances has resulted in a continuous decline in China’s domestic hot-rolled prices, and aggravated steelmakers’ performances. Desperate steelmakers have turned their eyes toward overseas markets in order to address oversupply, selling their products at low prices. Remarkably, China’s steel exports grew 50.4% in 2014, to 93.9 Mt, and surpassed 112 Mt in 2015, an increase of 19.7% YoY. Let’s take a look at the change in steel export items. In the early 2000s, China exported mainly cost-competitive products, such as steel bars, sections, and plates. With improved technologies, China has continuously made inroads into high-end overseas markets, such as galvanized sheets and boron-added alloy flat, thereby drastically increasing the shares of related items in exports.

China’s major steel export destinations have changed dramatically. In 2005, China’s steel exports to Northeast Asia, including Korea, Japan, and Hong Kong, accounted for 40% of total steel exports, but recently China has put effort into expanding exports to the ASEAN market, which is the world’s largest import market and a recipient of large-scale investments in infrastructure. As a result, China’s exports to the ASEAN have increased noticeably,
at a CAGR of 33.2% since 2010. In particular, the share of China’s steel products in the Philippines and Vietnam rose by 52.5%p and 23.2%p, respectively from 2010 to 2015, because Chinese products emerged as an alternative to Russian products, on which neighboring countries imposed trade restrictions following the Russia-Ukraine conflict over Crimea. As a result, the ASEAN has become the major neighboring export destination for Korea, China, and Japan. The share of the three Northeast Asian countries in the ASEAN-6 (Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam) increased from 52.4% in 2005 to 70.2% in 2014.

China is also expanding its footprint in the Middle East. China’s steel exports to Lebanon, Saudi Arabia, and Jordan increased at CAGR of 86.1%, 73.5%, and 35.6%, respectively, from 2010 to 2015. China’s steel exports to

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**China’s Steel Export Growth**

Note: *denotes CAGR from 2010 to 2015
Source: Mysteel
South Africa rose at a CAGR of 34.5% during the same period. From neighboring countries to the ends of Africa, China has succeeded in diversifying export destinations for its bulk supply of steel products.

**Japan leaps forward with investment in high-quality steel, taking advantage of locking-in demand**

Leading Japanese automakers, such as Toyota and Honda, began establishing overseas production bases in the 1980s, and further expanded into China in 2000. In the 1990s, Japanese mills implemented passive strategies of simply exporting steel materials and high-quality steel products to localized steel-consuming industries, such as automotive, energy, and home appliances. In the 2000s, however, market conditions suddenly changed. Japanese steel mills were forced to find new markets, because their major export markets were attacked by cheap Chinese products, and China and Korea’s steel markets gained self-sufficiency. Therefore, Japanese steel mills adopted active strategies to boost the supply of pre-processed original steel materials to local mills invested by the Japanese companies. Japan began operation of downstream facilities in Thailand, based on Thailand’s stable demand for high-quality automotive steel sheet, and created new demand through joint ventures with local mills in the USA and Mexico. Accordingly, Japan has expanded its market in the face of heavy inflows of cheap Chinese products; Japan’s steel exports to the USA, the ASEAN, and Mexico increased at CAGR of 7.4%, 1.5%, and 12.0%, respectively, from 2010 to 2015.

Japan is also actively investing in high-quality steel production, mainly in areas with well-established production networks. In 2014, Nippon Steel & Sumitomo Metal Corporation (NSSMC) implemented overseas downstream operations, including TENIGAL in Mexico, NSGT in Thailand, and NSBS in Singapore, in order to meet demand for and secure supply of high-quality cold rolled sheets exclusively for the automotive industry. It plans to produce high strength steel and advanced high-strength steel (AHSS) at JCAPCPL, a joint venture with India. NSSMC is expanding facilities in the USA. This shows that NSSMC has moved
beyond exporting steel materials and high-quality steel products, toward local production of high-strength steel, solidifying its footing in overseas markets.

**Korea gears up to meet demand for steel materials through overseas downstream investment**

Influenced by sluggish domestic demand due to mature industries and the market dominance of Chinese products, the Korean market became saturated. Desperate for new markets, Korea followed in the footsteps of China, simply exporting products overseas and diversifying export destinations. As a result, Korea ended up in a difficult situation, between China’s heavy exports of cheap products and Japan’s steel materials and high-quality steel. Korea began investing in downstream facilities in overseas markets, including Turkey, Mexico, and India. Following the successive completion of these downstream facilities in the mid-2000s, Korea gradually opened routes for the supply of steel materials. Korea’s steel exports increased a record-breaking 10.5% in 2014.

Once production of galvanized sheets and stainless steel cold-rolled (STS CR) began in Mexico and Turkey, where Korea has made investments in downstream facilities, Korea achieved real results. Korea’s steel exports to Turkey and Mexico increased at CAGR of 36.1% and 10.7%, respectively, from 2010 to 2015. P-Mexico began operation of a 900,000-tonne galvanized sheet facility for automotive, home appliances, and construction, in two phases, in 2009 and 2013. Accordingly, the share of its key steel material, cold-rolled (CR) coil, increased to 35% in 2014. Vietnam-based P-VIETNAM and P-VST and Thailand-based P-Thainox began producing CR, STS CR, and electrolytic galvanized sheets (EG). Related steel materials, such as HR and STS HR coil, account for 53% of steel exports. Despite the new downstream operations in Vietnam, Korea’s exports to Vietnam rose only 2.6% from 2010 to 2015, owing largely to heavy inflows of cheap Chinese products. Considering Vietnam’s high economic growth, there is much room for exports to increase. All in all, Korea is gearing up to increase the supply of steel materials through strengthened local strategies in order to increase steel exports.
High Export Similarity Index in Northeast Asia

This article has reviewed the change of the steel trading landscape among Korea, China, and Japan. Has competition for exports intensified among the three countries following the transition of the trading patterns? Taking a look at the Export Similarity Index (ESI), Korea and Japan have been in competition for the last ten years, and China’s rapid rise has intensified competition between Korea and China, and China and Japan. Korea and Japan’s ESI is high, over 0.7 between 2005 and 2014. Korea and China’s ESI increased from 0.55 in 2005 to 0.68 in 2014, and China and Japan’s ESI increased from 0.68 in 2005 to 0.7 in 2014.

Competition for steel exports among Korea, China, and Japan has intensified. As the USA, EU, and the ASEAN strengthen protectionist measures for their steel industries, global steel trade will contract and heighten the rivalry among the three countries.

The Export Similarity Index (ESI) measures the extent to which two countries compete by exporting the same products in a certain market. The index ranges from 0 to 1 and a higher value denotes that the composition of exports between the countries is more similar. Export and import data of Korea, China, and Japan are those from the World Steel Export (ISSB) on 27 steel products in 80 countries.

\[
ESI_{ab} = \sum_i \frac{MIN[X_i(a)/X(a), X_i(b)/X(b)]}{X_i(a)}
\]

ESI for steel of Korea, China, and Japan in world market

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2007</th>
<th>2009</th>
<th>2011</th>
<th>2013</th>
<th>2014</th>
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<td>0.76</td>
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</tr>
<tr>
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<tr>
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<td>0.65</td>
<td>0.70</td>
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