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ARTICLE

Cities of Vanadium: Technological Development and Post-Industrial Transformation in Emalahleni, Nizhny Tagil, and Panzhihua

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ABSTRACT
The paper investigates the trajectories of social and economic development of second-tier single-industry cities specializing in metallurgy of vanadium under the circumstances of post-industrial economy. In the middle of 20th century, a technology of processing titaniferous ore made it possible to use vast deposits of previously unexploited natural resources to produce steel and vanadium. The large integrated steel mills were erected in Witbank (Emalahleni) in South Africa, Nizhny Tagil in Russia, and Panzhihua in China. Being industrial monotowns dependent on mining and metallurgy, these cities were seeking for diversification which could provide sustainable development. Such diversification was generally following two directions: either establishment of belt of smaller technological enterprises and creating section of product with higher added value, or growing the system of industries of culture, leisure, and health. While Emalahleni failed in striving for diversification due to boom in coal industry, which ultimately led to bankruptcy of its steel industry, Nizhny Tagil and Panzhihua remained successful steel-making centers even in 21st century. However, even economic success and focused attempts to diversify city's economy by means of creative reindustrialization were circumscribed by the cultural and environmental issues caused by the very fact of such industrial survival.

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Introduction: The Problem of Creative Reindustrialization

The problem of deindustrialization and subsequent economic and social depression in industrial centers is among the key issues of recent urban studies and historical research (Culter, 1999; Koistinen, 2013). The "classical" image of a depressive manufacturing city emerged from the dramatic experience of the economic crisis of 1970s in industrial centers of United States (the cities of so-called Rust Belt), United Kingdom, or France (High, 2013; Strangleman et al., 2013; Zukin, 1985): the fall of production with the subsequent lay-offs, shrinking of tax base, and loss of population (Feldman & Leana, 1989, p. 55). As Neumann (2016) emphasizes, "contemporary narratives of the inexorable decline of basic industry in North America and Western Europe make the postindustrial transformation of national economies and old manufacturing centers seem like a historical inevitability" (p. 3). However, the processes of deindustrialization varied from place to place. While the deindustrialization on greater scale was soon followed by the emergence of "new economy" based upon the tertiary sector and the knowledge-intensive service providing, this development was uneven, and many former industrial cities suffered crisis. As Cowie and Heathcott (2003) emphasize: "We should see this political-economic order and the culture it engendered as temporary and impermanent development in space and time" (p. 5).

Anyway, by the end of 20th century, *sustainability* emerged as key feature of a successful city: "For a city to be considered sustainable, certain important elements must be present. These elements (sustainable education, renewable energy, energy efficiency, sustainable transportation, sustainable buildings, waste management, etc.), when combined with informed and willing inhabitants, dividends of sustainability may be realized" (Sodiq et al., 2019). The diversification (restructuring) of city's economy to increase sustainability had become the most important issue (Koritz, 1991; Lord & Price, 1992). Among the ways to assure sustainable development through increasing diversity was the concept of *cultural economy*. Trubina stresses: "Cultural economy is a significant sector of the economy as a whole. This is due to the fact that capitalism today is probably at a stage of development when cultural forms are embedded in productive activity, and culture as a whole is subjected to various options of commercialization and commodification. The production and marketing of goods and services presuppose endowing them with aesthetic and semiotic features, and in general they turn out to be objects of symbolic economics" (Trubina, 2011, p. 243;

Trans. by Konstantin Bugrov—K. B.). Within the context of economic change at the turn of 21st century, cultural economy started to be seen as creative economy (Florida, 2003; Landry, 2008). The concept was criticized for ascribing innovative capacity to artificially aggregated group of "creative class" and for neglecting the role of factors other than "technology, talent, and tolerance" (Krätke, 2010, pp. 6–7).

However, the key feature of the creative city is not to innovate, but to attract wealth. Landry (2008) puts it like this: "Every city of real ambition wants to move up the value chain and capture centrality for themselves and become a central hub of wealth creation by exporting, yet controlling from a distance, low-cost activities and attracting high-value ones to itself" (p. xviii). The creative economy is based on attractiveness, and if creative environment plays pivotal role in the attraction of creative persons (be it producers or consumers) into the city, then narration and imagery emerge as the most important medium. Cunningham (2002) explained the difference between the old-fashioned concept of *cultural industry* and the new idea of *creative industry* in the following terms: "Interactivity, convergence, customization, collaboration and networks are key. Creative industries are less national, and more global and local/regional, than is typical among public broadcasting systems, flagship arts companies and so on. Their characteristic organizational mode is the micro-firm to small to medium-sized enterprise (SMEs) relating to large established distribution/circulation organizations" (p. 59). Kloudova (2010) stresses creative class's tendency to concentrate in large cities and describes two possible strategies for smaller cities: "First is to concentrate on creating conditions for creative economy, attraction of creative specialists and firms. For this, the open creative space, a network of educational institutions has to be installed … Second is to attract not creative firms but the consumers of their production, who can spend the money, earned in the center of creative activity, were spent there. That require, for instance, centers of leisure or locations for cultural or entertainment events" (pp. 121–122; Trans. by K. B.). Of course, these two strategies are interconnected, because both of them suppose the creation of certain environment. The *creative tourism* rose as a result of transformation of cultural tourism into more involving, interactive, appealing form of leisure (Rogerson, 2006, pp. 150–154). Tourism, therefore, must be considered as an integral part of creative industry being the key mechanism of attracting consumers (Richards, 2011). Moreover, creative tourism allowed the inclusion of new destinations beside traditional types of resorts; in particular, it opened the way for industrial cities to compete as tourist destinations, as in cases of Duisburg, Wolfsburg, or Lodz.

The rise of variety of creative industries might be called the *creative reindustrialization*, not in the sense that it literally replaces the shattered manufacturing industry in particular town, but in the sense that it follows the global discursive and cultural turn towards the sustainable, diverse, and creative development, which made even successful industrial cities sought diversification through the rise of creative industries. Since the process of creative reindustrialization develops on the basis of concentration and attractiveness, the metropolitan areas are naturally in better position to face it. For this reason, it is of particular to study

this process in second-tier industrial cities with a historical single-industry profile. Such cities are widely known as single-industry towns. Moreover, the concept of deindustrialization is valid mainly for the societies of Northern America and Europe; the things were different in other parts of the world, where emerging industries had to benefit from the collapse of American and European manufacturing giants. Steel industry had been in the focus of the attention of researchers. Of all the branches of manufacturing that suffered from deindustrialization, metallurgy was perhaps the most harmed. It faced severe discursive challenge, since it started to associate both with economic troubles and environmental harm. The aim of this paper is to examine the ways in which centers of steel industry, the second-tier cities from outside of the USA, Canada, and Western Europe, which historically emerged around the technologically similar branches of steel-making, faced the challenge of creative reindustrialization.

The steel industry across the globe is diverse; there are some distinct branches of metallurgy which are based upon specific approach to processing iron ore and obtaining different products. One of such branches is the metallurgy of *vanadium*. Vanadium is a metal that is used as an alloying agent for carbon steels, tool steels, and high-strength, low-alloy steels, as well as aerospace industry (Taylor et al., 2006, p. 80); since in improves the qualities of steel allows, it is known as "vitamin" for the steel. Vanadium is typically produced from titaniferous ore. This ore includes titanium dioxide which is hard to smelt in blast furnaces, and, therefore, titaniferous ore is difficult to use for iron-making, even though its deposits are rather abundant. Industrial use of titaniferous ore became possible when technologies of vanadium extraction were developed, that is, "precipitating a vanadium salt from a leach of a salt-roasted ore and precipitation from a leach of salt-roasted slag obtained after smelting the ore to make a vanadium bearing pig iron followed by an oxygen blow in a converter forming the vanadium-rich slag" (Taylor et al., 2006, pp. 80–81). These technologies were developed in the middle of 20th century almost simultaneously in South Africa (Emalahleni), the USSR (Nizhny Tagil), and China (Panzhihua). These three countries remained leading producers of vanadium for a long time (Moskalyk & Aftanazi, 2003). Each of mentioned metallurgical centers were on the list of world's largest steel-making hubs by the beginning of 21st century (Mazein, 2009). Each of them is typically characterized as second-tier city of their respective regions, the industrial centers outside the key metropolitan areas. And, due to their connection with the processing of complex titaniferous ore, each of them represented the science-intensive branch of steelmaking.

Thus, we narrow the scope of study to the second-tier, non-metropolitan cities with metallurgical specialization. Then, among these cities, we limit the scope of study to the three locations producing vanadium in South Africa, Russia, and China. We shall trace the historical trajectory of each of these "cities of vanadium" both in terms of their industrial development and their ability to transfer towards creative industries and sustainable growth, and then provide the comparison to see the trajectories of steel cities with similar industrial specialization under different national and historical circumstances within the post-industrial transition.

Emalahleni: Coal vs. Steel

The city of Emalahleni (formerly Witbank) lies 100 kilometers to the east from the agglomeration of Pretoria and Johannesburg, South Africa's largest metropolitan area. It was founded in 1903 as a center of coal mining. However, by 1950s it also became a center of metallurgy. At that time, South African steel market was dominated by state-owned Iscor corporation, and several local companies were attempting to compete by installing their own mills (Cross, 1994). The technology of obtaining vanadium through leaching was developed by 1950s on the basis of pioneering works of South African metallurgist Bleloch (Steinberg et al., 2011, p. 705). Bleloch's ideas allowed to exploit the vast deposits of titaniferous ore at Highveld plateau in the proximity of Witbank. In 1957, a small vanadium factory in Witbank was launched by Minerals Engineering Company, which in 1959 was acquired by Anglo-American Industrial Corporation, and so the factory changed the name to Highveld Steel and Vanadium Company. The vanadium slag was obtained in Witbank through pre-reduction in a rotary kiln and subsequent leaching in a sodium salt, then smelting in electric furnaces to produce vanadium iron which could be separated into vanadium slag and iron (and subsequently steel) in oxygen converter (Taylor et al., 2006, p. 82). By the end of 20th century Highveld Steel and Vanadium became the leading producer of ferrovanadium in the Western world, even though it never mastered the production of titanium (Dworzanowski, 2013, p. 682); additionally, it became nation's second-largest steel producer, after the large integrated mill, which Iscor operated at the city of Vanderbijlpark.

The general layout of the city is made by collieries; already in 1920s, the local landscape was dramatically changed, and the local authorities even promoted it as a "different kind of beauty," emphasizing industrial significance of Witbank for the needs of coal-driven electrification in South Africa (Singer, 2011, pp. 33–34). Emalahleni is half-encircled from the west by the coal mines and industrial sites like Highveld Steel and Vanadium plant and some other ferroalloys factories. The well-to-do quarters of the city are concentrated to the east of the railroad station and the oldest Witbank colliery, which is now defunct. The western part of the city, located in proximity to industrial zones, was occupied by poor areas since 1920s including the "informal townships" of Thushanang, Vosman, Lynnville, Kwa Guqa, and others. The environmental situation in Witbank became disastrous already in 1930s, though main threat were not steel mills but coal-fired power plants and coal dumps (Akinlabi et al., 2019).

Despite the success of Highveld Steel and Vanadium, Emalahleni was unable to become global exporter of steel. The industrial modernization of the country was driven by a narrow circle of huge corporations such as state-owned Iscor, Excom, and Sasol, and privately owned Anglo-American, which formed the dominant economic force of South Africa (Fine, 1997, p. 131). This "mineral-energy complex" relied upon the increase of global export. However, despite limited successes reached under the import-substituting politics of the apartheid era, the economy of South Africa was "trapped between its origin as an imperialist export enclave and an aspiration to become a fully modern industrial

economy which has been frustrated by continuing reliance on cheap black labor" (Hart & Padayachee, 2013, p. 60). After the collapse of apartheid, the combination of political crisis and neo-liberal turn in global economy led to massive capital flight out of country; most of local industry was overtaken by international companies.

In 1998, Anglo-American Industrial Corporation moved overseas, which some researchers considered to be the "loss of the champion" (Robinson, 2016, p. 774). Highveld Steel and Vanadium was unable to compete with Russian and Chinese steel exporters. In 2007, steel mill went bankrupt and was acquired by Russian corporation EVRAZ, which already possessed vanadium facilities in Russia. EVRAZ aimed at becoming world's leading producer of vanadium by concentrating Russian and South African facilities, but this attempt was unsuccessful. The steel industry of Emalahleni was plagued by the lack of trained personnel; the plan to install a national steel and metal fabrication hub in the area also went nowhere (Campbell et al., 2016, p. 76). In 2010s, the decline of steelmaking in Emalahleni was seen as a key risk factor for the local community, even though city's economy in general boomed due to high demand for coal and the population was growing in the period from 2001 to 2011 with annual rate of 3.6% (Marais, 2016, pp. 73–75). In 2016, EVRAZ halted the production at Highveld Steel and Vanadium (Marais et al., 2022, p. 15), signaling the demise of once-powerful South African vanadium industry. Part of the mill survived, being acquired by ArcelorMittal group and transformed into a "structural mill" aimed at production of rails and structural steel for purposes of construction, and the rest of the mill was transformed into business park.

However, this collapse, while being undoubtedly the result of defeat in international competition, did not lead to deindustrialization; the coal mining at Emalahleni flourishes and is seen by local administration and business as the key factor of economic and social stability (Marais et al., 2022, p. 157). Coal mining remained the dominant force in making the urban layout of Emalahleni, as the city continue to grow due to migrations from rural areas. In 2011, it was a typical mining town, as coal mining made up 36% percents of its GVA and 30% of employment, while manufacturing made up 5.8% and 16.8% correspondingly; the local economy became totally dependent on coal (Marais et al., 2022, p. 40).

The coal mining, much less demanding in technological sense than metallurgy of vanadium, did not created opportunities for any sort creative reindustrialization. Even the tenants of Highveld Business Park that emerged in place of former vanadium mill are mainly operating in different fields related to services in coal mining. No particular creative strategy had been applied to solve economic issues at Emalahleni. There are some local cultural and leisure facilities, that is, Witbank Civic Theatre and The Ridge Casino, though nothing more than that. The tourism is not developing: in 2017, 85% of all trips to Emalahleni were visits to friends and relatives, while leisure and business trips accounted for only 8% (Emalahleni Local Municipality, 2017, p. 89). In 2020, Emalahleni tourism strategy, while referring to the natural beauty and industrial history of the area (and, in particular, proposing to establish a museum of mining), emphasized various threats, including deteriorated social infrastructure, crime and violence on visitors, and environmental security.

Emalahleni gained negative image of polluted city with poor administrative management. The problems with air pollution are complemented by the blackouts and shortages in water supply, caused by city's rapid growth with which obsolete communal infrastructure fails to cope. The biggest polluter, state-owned power-producing Eskom, is unable to comply with the state regulations in terms of emissions. For instance, in 2018, some local newspaper in Emalahleni proclaimed: "We have the dirtiest air in the world" (Goldswine, 2018). Additionally, the acid mine drainage remains serious threat to the local river system (Laisani & Jegede, p. 1590). In general, Emalahleni administration prioritized mineral wealth above social, agricultural and environmental concerns (Campbell et al., 2017, p. 223).

Nizhny Tagil: Paradoxes of Titanium Valley

Nizhny Tagil is an old steel-making town in the Ural Region of Russia: the local mill started production as early as the 18th century, although it has subsequently undergone a number of reconstructions. In Soviet era, new integrated mill was erected in 1940 (Mikheev, 2024, p. 60), with blast furnaces, steel-melting and rolling facilities, as well as large coke plant. Initially, this *Nizhnetagil'skii metallurgicheskii kombinat*, or *NTMK* [Nizhniy Tagil Iron and Steel Works], was using high-quality iron ore of local mines; however, in the middle of 1950s, the deposits of this ore were exhausted, and the new reconstruction project was launched to exploit vast deposits of titaniferous ore from Mountain Kachkanar located 112 kilometers away. In addition to general problems with smelting, this ore was rather poor in iron, therefore, two problems had to be solved: the technology of ore dressing, and the technology of smelting it in blast furnaces. There was a debate about technological possibility and economic justification for this costly project. Since 1930s, the idea of producing vanadium from titaniferous ore was discussed by the local scientists, and now it became an argument in favor reconstruction. Several other technological innovations were implemented at NTMK in 1960s and 1970s: the USSR's first oxygen converters were launched in 1963, and the first experimental continuous casting machine was installed in 1968. By the end of 1980s NTMK was able to produce 5.5 million tons of steel.

However, NTMK did not concentrate the finishing stages of vanadium processing. Instead, the vanadium slag was delivered from NTMK to Tula where final production facilities were deployed. Another valuable metal that could be obtained from titanomagnetite, titanium, was merely dumped, since no technology of its extraction was developed. In the proximity of Nizhny Tagil another plant in smaller town of Verkhnaia Salda was producing titanium from ilmenite ore of Volnogorsk and Irshansk Combines located in Ukraine. Thus, within the entangled planned economy of Soviet Union, vanadium slag was making its way nearly 2,000 kilometers to the west, while ilmenite had to travel the same distance to the east.

The city's layout corresponded with the development of its industrial economy in 20th century. Generally, Nizhny Tagil was sandwiched between the old iron mine and mill in the west, and the new integrated mill in the east. Some smaller living districts are scattered in the industrial zone of NTMK. In 1930s, another large

factory, *UralVagonZavod,* or *UVZ* [Ural Wagon Plant], was established, with its own settlement located 11 kilometers to the east. However, NTMK retained key influence upon city's social life. In 1970s, when environmental pressure of the steel mill became obvious, it launched the construction of large living massive in the southwest, as far from the source of pollution as possible. Indeed, environmental issues became crucial by 1970s. NTMK was emitting nearly 600,000 tons into the air; on the other side, the extensive mining at Mountain Vysokaya led to serious threat for the landscape. When in 1988 a new coke furnace was erected with serious shortcomings, the wave of protests swept the city, which became the center of the environmental movement of *perestroika* years. Environmental upheavals were soon followed by the economic collapse; the combination of these factors threatened to send Nizhny Tagil the same way of decline that the American cities of the Rust Belt had already went through.

However, the Russian steel industry was saved from the collapse through export. While in 1980 the USSR exported only 6.2% of its rolled steel output, by 1998 the share of export in Russian metallurgy grew to 62% (Fortescue, 2009, p. 253), as former Soviet mills substituted the decreasing domestic demand for fulfilling the needs of Western countries. Even though Nizhny Tagil suffered severely from the crisis, the lay-offs in industry (several smaller factories went bankrupt) and overall poverty, the city never went through the deindustrialization (Turgel, 2009). In 1995, NTMK was acquired by industrial holding EVRAZ. The new owners benefited from the cheap workforce, raw materials, and electric power; in addition, they were capable of investing into technological reconstruction of their facilities more effectively than Soviet government did, even though this reconstruction was mainly implemented with the assistance of Western firms which provided technologies and equipment to make production more effective and environmentally friendly (Saveliev et al., 2020, pp. 552–554; Temnikov et al., 2018). However, despite its stable position, NTMK was gradually lowering employment due to new technologies and automatization, and its social role was shrinking.

Nowadays, Nizhny Tagil has 332,292 inhabitants. Nihny Tagil surely possessed some capacity to grow as a creative center. There are renowned art school and pedagogical university in the city. The old steel mill had reputation of a valuable monument of industrial history, and in 1987 it became a museum. The local intelligentsia of 1980s clearly intended to shape Nizhny Tagil as a "mining-metallurgical ethnical park", and in 2010, they developed the concept of an "Eco-Industrial Technopark". Since 2000, local authorities pursued the creative strategy by installing tourist facilities around Nizhny Tagil. At Mountain Belaya, a ski resort was opened in 2003–2006, while in Nizhny Tagil and in neighboring old factory town of Chernoistochinsk two creative clusters were installed in 2021. Since 2018, EVRAZ launched its own industrial tourism program. In 2022, the number of visitors to Nizhny Tagil exceeded the number of its inhabitants, reaching 400,000 people. At the same time, an attempt was made to create special economic zones to stimulate science-intensive production. In 2010, such zone under the title of *Titanovaia dolina* [Titanium Valley] was opened halfway from Nizhny Tagil to Verkhniaia Salda, and in 2011,

a Chemical Park was installed in Nizhny Tagil. The number of employees at the steel mill is approximately 13,000 people (by the end of Soviet period it was 30,000, and in 2017 it was 23,300); to compare, the total number of people working in non-state sector of Nizhny Tagil's economy was 108,100 people, of them small or medium businesses employed 42,200 people. Thus, heavy industry still dominates the employment in the city, yet the prominence of steel mill fell considerably over past decades.

The environmental problems of the city became a cliché in public sphere, damaging the reputation of the city and showing Nizhny Tagil as a polluted place full of industrial ruins. The environmental policies of NTMK were summarized in 2018 in a report, which states that "open and available to anyone reliable information about the condition of environment allows to remove many doubts and promotes social stability in the city" (Itogovyi Dokument, 2019, p. 26; Trans. by K. B.). It also emphasized the difference between the overall control over emissions and the specific control over odor; even though the share of unpleasant-smelling emissions is low, it usually provokes complaints, and so special system of managing such odors has to be implemented. In other words, technological and environmental improvements at NTMK were at odds with the degrading public image of Nizhny Tagil, which was further damaged by the popular TV show which in 2011 presented Nizhny Tagil as an uncultured city, populated by hooligans.

Thus, the city faced rather paradoxical effect of "tantalizing": while the steel mill operates successfully, and a set of clever policies is implemented to diversity the city's economy, the overall effect is negated by the unfavorable public opinion regarding environment, shortage of new housing, and worn-out communal structure. The local museum and school of arts did not have enough support to turn into the anchoring public centers. The attractiveness of the city remains limited, and the public image is still controversial.

Panzhihua: The Capital of Vanadium and Titanium

Panzhiua's ore deposits in southwestern China were discovered in 1930s, and the idea of industrial colonization of this remote district was growing steadily among Chinese political establishment (Kinzley, 2012). In 1960s, the ambitious program of the "Third Front" was launched by Chinese government: a program of industrialization of mountain areas lying far from the seashore ("First Front") and old industrial districts in the North ("Second Front"), and thus protected against the possible attacks from either the USA or USSR. In the distant southwestern part of the province of Sichuan, a vast deposit of titaniferous ore was drawing attention; it was planned to install a steel mill to produce steel and additionally vanadium. The construction was among key priorities within the whole "Third Front" (Tan et al., 2021). In 1970, Panzhihua Iron and Steel (Group) Company Limited, or Pangang, started to produce iron; the city gained a new name, Dukou (since 1987 the city again became known as Panzhihua). However, only in 1979 smelting of local ore was mastered by Pangang with the assistance of a collective of researchers led by prominent metallurgist Zhou Chuandian. Unlike NTMK, Pangang produces both vanadium slag and ferrovanadium.

The "Third Front" was the first Chinese major project after the dismissal of Soviet technological assistance, and as such it saw many technological achievements by Chinese scientists and technicians, yet at the same time faced many serious problems (Naughton, 1988, p. 377; Sugimoto, 1993, p. 270). In Chinese media, the foundational role of steel-making in Panzhihua for the development of remote Western districts of the republic is referred to as "iron bowl of rice." As a strategic facility, Pangang remained secret until 1990s, and in 1985 an author from South Africa mistakenly indicated two vanadium powers, the USSR and South Africa, as possessing 95% of titanomagnetite ore deposits of the world, being apparently unaware of Panxi's resource opulence (Rohrmann, 1985, p. 143).

The city of Panzhihua is made of several living areas along the rivers Jinsha and Yalong, making up the Western and Eastern districts. Today, Panzhihua is characterized as a mountain city and resource-based city (Yang et al., 2021), or a medium-sized industrial city dominated by iron and steel (Xiao et al, p. 1). In 2019, the metropolitan area of Panzhihua had population of 700,000 people (Qin & Yang, 2019, p. 3). The nearby area is the zone of intense mining, which include "three extraordinary mines of Hongge, Baima and Panzhihua" (Huang, 1996, p. 121). The steel production in Panzhihua was increasing over time: in 1992, Pangang produced 2.4 million tons of steel (Huang, 1996, p. 124), while in 2009 it was capable of producing 7.8 million tons, and this capacity increases. The competition with the other Chinese steel mills in the light of extreme remoteness made Panzhihua seek science-intensive strategy of growth. However, the threat of resource-dependency was recognized by local authorities already in 1990s. Since 2001, under the 10th Five Year Plan, Chinese metallurgical enterprises were encouraged to "develop one main business and diversified subsidiaries" (Li, 2020, p. 384).

The new strategy, pursued by Panzhihua governance since 2004, was twofold. On the one side, it was aimed at promoting forestry, agriculture, and overall environmental sustainability to develop tourism. In 2017, the city was honored as National Garden City and National Forest City. In 2021, a hydroelectric power station was constructed on the Jinsha river, which led to significant decrease in consumption of fossil fuels (Zhou et al., 2019). The environmental policy at Panzhihua is typically characterized as successful, with the significant improvement in terms of air quality, and allowed to create rejuvenated urban environment, as "investments were poured into ecological maintenance, the health and wellness industry, and constructing a city that was attractive to tourists" (Yang et al., 2021). Panzhihua started to position itself as "city of sunshine and health care" due to its unique climate specifics, and the concept of "path of sunshine health" was developed to attract more visitors into the area (Xiao et al., 2020, p. 3). Among Chinese researchers the transformation of Panzhihua is typically seen as successful example of diversification (Li et al., 2015, p. 15). One of official press releases circulated by the local authorities proudly proclaimed: "Panzhihua is a city of sunshine and flowers in southwestern China, and a world-class model for resource-intensive industrial cities yearning for green transformation and development" (The Environment Protection Bureau of Panzhihua, 2019). To organize the branding and tourism politics, a firm called Panzhihua Sunshine Poetry Culture Propagation Co.,

Ltd. was established to promote the tourism products of so-called Panzhihua Story, including the selling of light jewelry and utensils made of titanium (Jiang & Dai, 2016, p. 480; Yang & Luo, 2019, p. 14).

Moreover, by 2011, Pangang managed to develop the technology of producing titanium from its ilmenite deposits. The ore deposits of Panzhihua contain 9%–10% of titanium oxide, and so they could, with proper beneficiation, be used for production of ilmenite concentrate, even though the recovery of titanium is quite low due to presence of calcium and magnesium (Filippou & Hudon, 2020, p. 23) Therefore, titanium dioxide is being produced from ilmenite using the sulfate process, rather than chlorination, which poses environmental issues (Li et al., 2006). Thus, Pangang become world's leading producer of vanadium and titanium, while at the same time remaining important supplier of steel. In spatial terms, that led to construction of new industrial complex to the southeast from Panzhihua, on the banks of the Jinjiang river called the Vanadium and Titanium Industrial Park (Xie, 2009). This industrial transformation is, again, typically seen as one of successful cases of industrial diversification in Chinese metallurgy (Li, 2020, p. 41; Li et al., 2015). To include its industrial imagery into the broader politics of creative development, Panzhihua authorities started to shift the public image of the city from iron and steel to vanadium and titanium, for it sounded more innovative: "After the concerted dedication of several generations, Panzhihua Iron and Steel Co. overcame the world-class problem of smelting high titanium vanadium vanadium-titanium magnetite with ordinary blast furnace, gradually actualizing scalable utilization of iron, vanadium and titanium, and garnering feats lauded across the globe" (The Environment Protection Bureau of Panzhihua, 2019). It was aimed at emphasizing the superiority of Panzhihua as a global center of technological excellence in the field of metallurgy of vanadium and titanium, to present the city as Vanadium and Titanium Capital of China. The local media refer to Panzhihua as "City of Heroes" or emphasize certain "spirit of Pangang", the specific ability, inherited from the era of "Third Front", to overcome difficulties, be it construction of a huge mill in the remote area in 1960s, or the competition struggle under the free market conditions in 2000s.

However, more detailed studies, undertaken by L. Dai, revealed inherent problems in Panzhihua steel industry which was suffering both from old-fashioned style of governance and from its geographical location in the distance from key consumers; even "sunshine and healthcare industry" is seriously limited by transportation inconvenience (Dai, 2019). The industrial and cultural heritage of the "Third Front" also represents a problem, since the approaches to promote it are unclear yet. At least some authors recently emphasize the historical and cultural value of the industrial heritage of "Third Front", particularly in Panzhihua (Zhang & Rui, 2017, pp. 371–372). The "Pangang spirit" is not turned into a symbolic capital for the city. In 2019, Yang and Jiang were assessing the sustainability of Panzhihua rather sceptically: "First, the supply-side structural reform makes the competition of Panzhihua Iron and Steel more fierce. Second, Panzhihua vanadium and titanium products are single, scientific and technological content is not high; third, Liangshan, Lijiang and Chuxiong, the surrounding cities of Panzhihua City, have great competitive power in the healthy and tourism industries, at present, Panzhihua has a good

development momentum of health and tourism, but the total amount is still small, and the natural environment and scenic spots are still relatively lagging behind. Fourth, it is lack of cultural and creative industries" (Yang & Jiang, 2019, p. 593). The number of employees at Pangang was around 100,000 at the beginning of 21st century and already in 2015 was still incredibly high by global standards, reaching approximately 70,000 people (though that number also includes the employees at minor mills in Chengdu and elsewhere); in the last decade, there were drastic staff reductions at Pangang. The current importance of Pangang in the structure of employment in the area is comparable to that of Nizhny Tagil steel mill, accounting for approximately 10%–15% in overall employment of the city.

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The "cities of vanadium" had much in common: they were resource-dependent single-industry cities, capable of developing innovative production due to advances in science and technology. In the post-industrial era, these cities remained bastions of industrial production, even though each of them faced severe shock by the end of 20th century: the collapse of apartheid and marker reforms in South Africa, the collapse of planned economy and privatization in Russia, and the transition to market in China. However, within the context of global economy their historical trajectories of development were different. In Emalahleni, the whole metallurgical segment was dismantled with all the sophisticated steel-making and vanadium production going nowhere. At the same time, the continuous growth of the city due to unfinished demographic transition (delayed by apartheid) and increase of coal-mining prevented diversification of local economy in Emalahleni. South Africa encountered the severe urban crisis in 1990s, under which housing and public facilities went even worse than they were under the apartheid (Bond, 2000, p. 363). In Nizhny Tagil and Panzhihua, the mills survived, yet the growth of these cities stopped. The heavy industries like steel-making dominated these cities financially while accounting for 10%–15% of employment within the city. Such stabilization created certain conditions for further diversification, albeit shaped by the presence of these steel-making heavyweights.

Both Niznhy Tagil and Panzhihua sought diversification and new market strategies, which led both to reconstruction of mills and to attempts at developing science-intensive production and to promote cultural industries and tourism. The serious challenges for these strategies include environmental issues, problematic cultural status of industrial heritage, and overall capacity of metallurgical industry to support creative and innovative sector. The creative reindustrialization, which relies upon cultural authenticity and attractiveness, was troubled in these cities since steel mills, which once formed the cultural core and specific "spirit" of settlements, became suspectful sources of pollution. Thus, economic trajectories of steel and vanadium mills were defined by the complicated interactions within international competition and ownership. In turn, even the cities which avoided the destiny of de-industrialized Rust Belt were trapped within the complexity of converting their economic strength into the post-industrial attractiveness pivotal for successful creative development.

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