


## Green port impact of the development of the sustainability in port cities

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### Abstract

Seaports and cities are internally linked, and the port can have a strong influence on the city, especially in the environmental aspect. Port authorities around the world are striving for greener forms of port management to adapt to state policy and to increase their economic and environmental competitiveness. The introduction of the concept of sustainable development in the port can stimulate the creation of green cities. This paper uses a case study to analyze the sustainable development in the Twin Port of Bremen. The aim is to distinguish the green port's impacts that can stimulate the development of the green city concept. It is shown that the port development stimulates GDP growth, increases employment, urban infrastructure development, and the overall enrichment of port cities. Using the presented analysis of the green port, the most important affecting factors are proposed.

### Introduction

Ports and cities are internally linked, since they interact and can stimulate each other's development. The ever-increasing requirements to reduce the negative impact on the environment, without compromising economic growth, require the introduction of the concept of sustainable development in both systems. The aim of this paper is to identify the impacts of the green port that can stimulate the development of the green city concept. In addition, a case study was carried out to indicate the port's activities in the field of sustainable development of the Ports of Bremen and Bremerhaven.

Aspects of the green port concept were positively implemented and developed in the Twin Port of Bremen, which can act as an example and the basis for expanding the concept to a larger area. The analysis of individual elements of the concept, and areas of

their implementation, brought answers to the topic of the possibility of connecting and stimulating sustainable development in the city. So far, the focus has been on researching green aspects in ports or cities. No attempt was made to demonstrate the impact of green ports on city functioning and the development of green cities. The OECD considered the competitiveness of the port cities and tried to establish policy recommendations to increase the positive impacts of ports on their cities (OECD, 2021).

The structure of the research is as follows: a literature review analyzes the scientific literature starting from the topic of sustainable development in ports and cities. Next, it describes the relationship between the city and the port and the environmental impact of the port. Then, the article presents the methodology, i.e., the case study and where the data used for the research originates from. The next part contains a case study about green ports sustainable

development strategy, which indicates the impact on the city and briefly describes the evolution of the port and city development. Additionally, this section indicates the impact of the green ports that may stimulate the development of the green city concept. Finally, at the end of this work, conclusions are presented.

## Literature review

Relations between ports and cities have developed over the years, as a result cities and ports have become cooperating systems. Such port cities primarily integrates transport and urban systems. It is a link between the local and global economy. However, the cooperation of cities and ports does not always cause their mutual stimulation, sometimes it limits their development.

Hoyle has presented a report on relations between the city and the port (Table 1). The author points out that initially the city and port showed a close relationship in terms of space and functionality, i.e., they formed a single system (Hoyle, 1989). In the following years, alongside the progressing industrial development, ports occupied new and larger spaces that separates themselves from the cities. However, after the modernization of ports over a period of time, the port-city connections were renewed. Globalization and intermodalism, as well as the progressing development of city and port areas, have had an impact on their reconnection.

Until the 19<sup>th</sup> century, cities developed in the immediate vicinity of ports and were functionally connected. Successive changes can be seen in these relations, in the direction of separation of the regions of these two systems. However, their internal connections are preserved. Port cities and ports have special development potential. The port, as a large

transport hub, performs activities on a national and international scale. We can consider ports as composite economy systems in various aspects. However, the port not only fulfills transport and industrial functions but also commercial factors and logistics, and affects the location and development of the city and the region (Montwiłł, 2011). Increasingly more often, elements of the natural environment are used as an integral component of the port infrastructure system. Even countering the often costly perception of the environment as a “green handbrake” for port development (Taljaard et al., 2021)

Both cities and ports are faced with the need to harmonize economic activities aimed at their development and environmental aspects. They can play a key role by introducing a smart sustainable development (Girard, 2013). The World Commission on Environment and Development defined the concept of sustainable development as “A process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations” (WCED, 1987, p. 46). Elkington distinguishes three categories in which the concept of sustainable development should be defined: economic prosperity, environmental quality, and social justice (Elkington, 1997).

It is important, in the last two decades, that port management began to become increasingly more regionally diversified (Lee & Lam, 2017). Governments and international organizations, such as the EU, have an important impact on port activities. In addition to European Commission directives, the European Sea Port Organization (ESPO) promotes environmental management, policies, and plans in European ports. In order to promote the Green Guide ESPO, in 1999 the institution established the

**Table 1. Evolution of the port-city interface (Hoyle, 1989; Hesse, 2013)**

Stage	Period	Characteristics
Primitive city	Ancient/medieval to 19 <sup>th</sup> century	Close spatial and functional association between city and port.
Expanding port/city	19 <sup>th</sup> – early 20 <sup>th</sup> century	Rapid commercial/industrial growth forces port to develop beyond city confines, with linear quays and break-bulk industries.
Modern industrial port/city	mid-20 <sup>th</sup> century	Industrial growth (especially oil refining) and introduction of containers/ro-ro require separation/space.
Retreat from the waterfront	1960s – 1980s	Changes in maritime technology induce growth of separate maritime industrial development areas.
Redevelopment of waterfront	1970s – 1990s	Large-scale modern port consumes large areas of land/water space; urban renewal of original core.
Renewal of port/city links	1980s – 2000+	Globalization and intermodalism transform port roles; port-city associations renewed; urban redevelopment enhances port-city integration.

EcoPorts Foundation, a network of European ports with the aim of identifying significant environmental aspects of port activities, products, and services (ESPO). Furthermore, the ports play an important role in the success of the European Green Deal.

In order to create eco-ports as centers of sustainable mobility, the “Horizon 2020” financing program was implemented, and one of its programs relates to: “Green airports and ports as hubs for sustainable and smart mobility”. The expected impact of the program is to achieve zero-emission port operations by 2030. This includes reducing emissions from water transport and other modes of transport, which in turn will improve the air quality, biodiversity, circular economy, and reduce noise pollution (European Commission, 2020b).

Port operations bring important social and economic benefits. However, it is also the cause of many negative effects on the environment. Several authors’ suggestions are now presented. Bailey and Solomon claimed in their considerations that sea-ports are the main centers of economic activity, but also sources of environmental pollution that threatens the health of nearby communities. The main environmental aspects include: air pollution from port operations, including smog and particulate pollution, loss or degradation of wetlands, destruction of fisheries and endangered species, wastewater and stormwater discharges, severe traffic congestion, noise and light pollution, loss of cultural resources, contamination of soil and water from leaking storage tanks, gas releases into the air from chemical storage or fumigation activities, solid and hazardous waste generation, and soil runoff and erosion. They concluded that numerous approaches would be necessary to reduce pollution for ports, moving toward a sustainable operational model that serves a local region without damaging the health and integrity of local communities and ecosystems. In their further considerations, they focus mainly on air pollution (Bailey & Solomon, 2004).

Klopott distinguished in her work the top ten environmental priorities of European Ports: noise, air quality, garbage/port waste, dredging – disposal, dredging – operations, relationship with the local community, energy consumption, dust, port development (water), and port development (land) (Klopott, 2013). Darbra et al. presented the following environmental aspects: emissions to air (including gases, solid particles, and energy; dust is a significant contribution), discharges to water (e.g., waste waters, accidental releases during loading/unloading operations), releases to soil due essentially to industrial

activities, releases to marine sediments and activities affecting the seabed (such as dredging), noise (with its potential impact on population and fauna), waste generation and dredging disposal, loss/degradation of terrestrial habitats, changes in marine ecosystems, odors, resource consumption and port development (land and sea occupation) (Darbra et al., 2005). According to Marzantowicz and Dembińska, sources of negative environmental impact are port infrastructure, vessels and technical means of internal transport (suprastructure), technology means of operation and handling (in the range of goods and material trading), technical social facilities (in terms of human functioning in port and also passenger service) and the last source – communication and transmission technologies (pipelines and information technology services) (Marzantowicz & Dembińska, 2018).

In response to the above emerging environmental requirements, ports have begun to introduce the concept of a green port. The latter is a port that neatly fits with the concepts of sustainable development. An important aspect is to find a balance between environmental impact and economic interests (Chiu, Lin & Ting, 2014). The green port is presented as the product of long-term strategy for the sustainable and climate friendly development of the port infrastructure (Moon, Woo & Kim, 2018). Shao et al., as the main goal of the green port idea, consider creating a good ecological environment and high economic efficiency in the port, ensuring harmony between social and environmental aspects and providing adequate modern transport or logistics functions. One of the ports’ pro-environmental activities is also the implementation of the environmental management system (EMS), which allows managing environmental programs at the port by controlling and even preventing pollution (Shao et al., 2009). The concept also applies to the responsible behavior of all port participants, from management to individual employees (Oniszczyk-Jastrzębek, Pawłowska & Czermański, 2018). The green port concept is based on the integration of port activities, operations, and management. Green ports aim to reduce the negative impact on the environment, improve the quality of the natural environment of the port area, enable efficient use of its resources, and increase the level of environmental management (Anastasopoulos, Kolios & Stylios, 2011).

Increasingly more authors are examining the topic of sustainable development in ports. It is especially worth paying attention to the research undertaken by Bjerkan and Ryghaug. They examined the impact of social processes in the context of facilitating the

transition to sustainable development in selected ports. It has been shown that important elements affecting the development of transition paths may be the interplay and hierarchy of social processes (Bjerkan & Ryghaug, 2021). Other authors consider developing a sustainable economy using an intelligent system dynamics model. Moreover, they listed such issues as strengthening the strategic understanding of the port layout, increasing competitiveness and the level of services provided, enhancing people-oriented strategies, striving for sustainable development of environmental protection, and others (Xiu & Zhao, 2021). It can be seen that the concept of sustainable port development is evolving in an increasingly wider area.

When it comes to the sustainable development of the city, Nijkamp and Opschoor indicated that in a sustainable city the agglomeration of the economy, society, and environment should be linked and their negative impacts should be maintained at certain threshold conditions. The concept of sustainable development in the city is combined with the idea of a green city, which is environmentally friendly and maximizes the economic and social co-benefits (Opschoor & Nijkamp, 1997).

For cities, the term “green” also refers to environmental aspects and sustainable development. The EBRD (European Bank for Reconstruction and Development) describes green city as one that is primarily characterized by environmental protection with the intention of maximizing social and economic benefits (ERBD, 2016). Moreover, D’Amico et al. highlighted the complexity of the implementation, development, and redefinition of smart and sustainable logistics in port cities. They indicate that an important role is played by systemic thinking with particular attention to the economic, social, environmental, and technological layers (D’Amico et al., 2021).

The literature discussed port-city relations, the topic of green ports, or green cities and green city-green port relationships as one system. However, no attempts were made to distinguish the factors of the port’s impact on the city that could stimulate the development of a green city. Studies have been carried out to show supported or inhibited development of port cities in China (Kong & Liu, 2021). Therefore, recognizing the topic of the port-city relationship as important in relation to sustainable development and the concept of green port, the present author aims to identify the impacts of a green port that could stimulate the development of the concept of a green city.

## Methodology

The case study method was applied to the research. A main advantage of this method is the ability to collect large amounts of data and information and by a variety of tools that makes it easier to describe and understand unknown problems (Mielcarek, 2014). The case study method based on the collected information enables an in-depth analysis of the studied problem, presenting its specificity, its interaction with other elements of the organization, or its environment. This method makes it possible to indicate the activities of the port in the field of sustainable development and then identify the impact of the green port that can stimulate the development of the green city concept.

The case study involves the Ports of Bremen and Bremerhaven in Germany, which have introduced and effectively develop the green port concept. The research is conducted on the basis of relevant and available documentation on these ports, such as port authority websites, sustainable reports, environmental reports, and green ports concept sites. More information was sought from Eurostat data and official reports of public institutions. The articles that have been used originate from Scopus and Google Scholar databases with the subject of green ports selected.

## Case study ports of Bremen and Bremerhaven

The Port of Bremen and Port of Bremerhaven are twin ports in the north of the Germany. Both are located on the Weser River (Figure 1). These ports rank amongst the most important universal ports in Europe. The port of Bremerhaven is located 32 nautical miles from the sea. It serves container vessels,

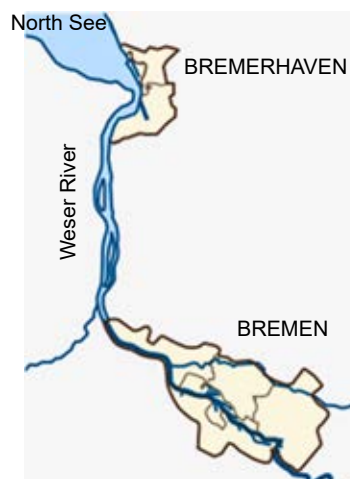


Figure 1. Ports of Bremen and Bremerhaven

car carriers, and RoRo vessels. 60 kilometers to the south are the Bremen terminals, which specializes on the transshipment of general and bulk cargo, heavy-lift, and breakbulk. Bremen ports are the landlord ports, which is the prevailing port model in medium- and large-sized ports in which port infrastructure is publicly funded and the transshipment activities are organized privately. The infrastructure of the ports of Bremen belongs to the Free Hanseatic City of Bremen and it is managed by bremenports GmbH & Co. KG.

At present, the maritime sector is a very important pillar of the economy of Bremen – since it accounts for over 30% of the economy of Bremen. In 2018, the region of Bremen exported the equivalent of €20.7b representing 9.8% of the total exports in Germany. In addition, Bremen is one of the richest cities in Europe, since it is also one of the largest industry areas in Germany. The GDP per inhabitant in 2020 in the Bremen region was €46,469 (Figure 2), significantly lower than in previous years – possibly due to the pandemic. As can be seen on the graph, GDP maintains an upward trend until this point in time. Around 40,000 people work in the ports of Bremen in over 1300 companies (European Commission, 2020a).

The data shows that the development of the port affects the improvement of the city. People who find employment at the port settle in the nearby areas and, as Figure 2 shows, they typically attain wealth. Companies related to the activity of the port are created to provide logistics, transport services, etc.

The analyzed port is the fourth largest container port in Europe (Figure 3) and the second largest in Germany, with 4.767 million TEU transhipped in

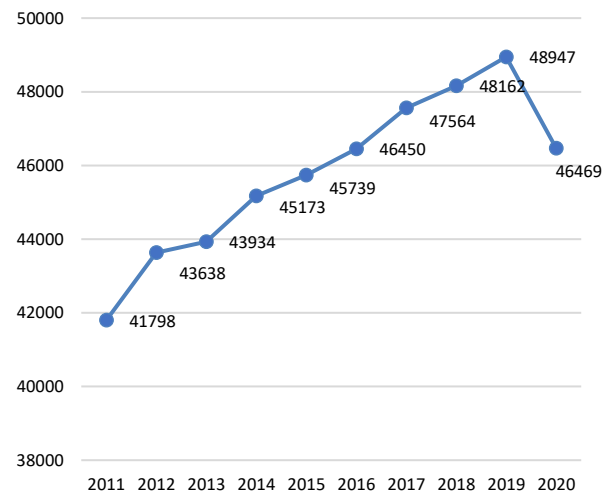


Figure 2. Bremen's GDP per capita (based on (CEIC, 2020))

2020. Bremerhaven is also one of the largest hubs for worldwide car transport. Of course, the large number of cars that arrive and high volume of containers handled by each port causes significant negative environmental effects.

The cooperation of the port and city over the years, which have both evolved over time, has brought developments for both of these entities. A significant change was the transfer of ports from the center of Bremen to its west side and to the coast. The cities and ports developed together, which provided territorial and administrative changes to the cities. The city of Bremen was unified with its existing rural communes, which resulted in the creation of one large administrative unit.

As its development progressed, both the ports and cities faced the need to continually reduce negative environmental impacts without compromising

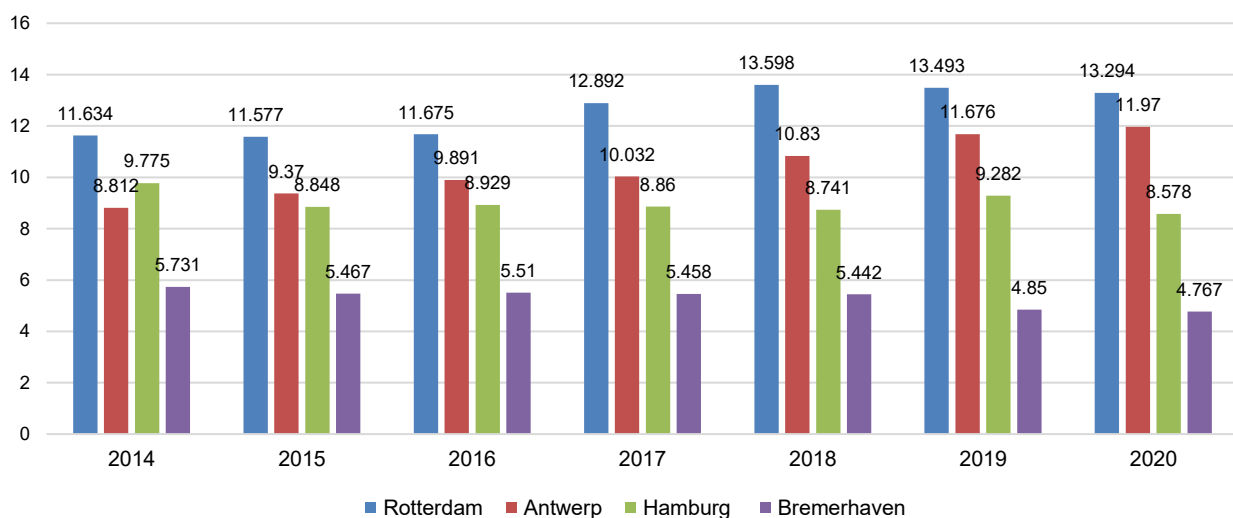


Figure 3. Top 4 ports in terms of volume (in TEUs) of containers handled in each port, by loading status (based on (Eurostat, 2021))

the economic growth. Both began to introduce more sustainable strategies. The port has adopted green ports sustainable development strategy that are developed specifically for the ports of Bremen/Bremerhaven. The green ports strategy of the analyzed port is based on a combination of ecological, economic, and social interests in order to ensure the future viability of the ports.

So far, the port authorities (i.e., the board of Bremenports) have focused on the immediate area of impact, but plans to expand their range to enable a fully sustainable supply chain to distribute goods inland. Good port management had an impact on creating an action plan for a sustainable and energy-efficient energy management, which transformed part of the port area into a nature reserve, that ensure the use of alternative fuels and deepens the output from the port. The ports of Bremen have included in their management plan the assumption that the operation and development of ports can be implemented in a sustainable and win-win manner (Lawer, Herbeck & Flitner, 2019).

Sustainability topics are listed in Table 2. They include five major pillars: governance, economic performance, environmental compatibility, staff and labor practices, and social responsibility. Moreover, the main activities undertaken in order to implement

good practices of sustainable development are included.

ESPO indicated the priorities in the implementation of the green port policy presented in Figure 4. Changes are mainly introduced in these areas.

As a first example, the air pollution from port activities and ships can easily reach cities. Bremerhaven monitors the port's impact on its surroundings. In this regard, there are designated places for measuring air quality. It is monitored at a total of eight permanently installed points in the cities of Bremerhaven and Bremen. It delivers data on nitrogen oxides, sulfur oxides, PM10, and PM2.5. Research showed compliance with air quality standards. In Bremerhaven sulfur dioxides fell from 22  $\mu\text{g}/\text{m}^3$  to 2  $\mu\text{g}/\text{m}^3$ , nitrogen dioxide pollution declined from 36  $\mu\text{g}/\text{m}^3$  to 20  $\mu\text{g}/\text{m}^3$ , PM10 has also fallen from 29  $\mu\text{g}/\text{m}^3$  to 17  $\mu\text{g}/\text{m}^3$ , and PM2.5 has increased from 10  $\mu\text{g}/\text{m}^3$  to 14  $\mu\text{g}/\text{m}^3$ . Over the past five years, Bremerhaven has reduced CO<sub>2</sub> emissions by 70%. This results from using renewable energy sources. Additionally, Bremenports has set itself the mid-term goal of becoming a carbon-neutral port (Bremenports, 2018).

It should be added that the port uses renewable energy for port operations and activities. Conventional vehicles have been replaced by electric hybrids vehicles. In Bremen, 21 berths have shore

**Table 2. Various aspects of sustainable development in the selected port (Bremenports, 2018)**

Twin Port of Bremen sustainability areas		
Governance:	Sustainability strategy & management Compliance Port Security & risk prevention Sustainable procurement	
Economic performance:	Competitiveness & major projects Economic value & indirect economic impacts Future-orientated infrastructure & adaptation to climate change	Increase productivity Ensure a demand-appropriate, cost effective, and resilient port (despite declining financial resources) Safeguard competitiveness (project-related cooperation) Strengthen importance of port industry and logistics for the regional economy Optimize the hinterland connection (modal shift to rail and inland shipping) Transformation to "green economy"
Environmental compatibility:	Use of resources and recycling in port construction & maintenance Effects of maintaining the water depths Energy management & climate protection Efficient land use & biodiversity Environmentally friendly shipping	CO <sub>2</sub> -neutral port (use new technologies and renewable energies) Develop port without the use of additional land (port cooperation) Reduce emissions (air pollutants, noise, and light) Conserve and recycle resources (closed loop recycling management) Conserve ecosystem functions on waterways (EU Water Framework Directive)
Staff & labor practices:	Attractive working conditions Fair working conditions Occupational health and safety	Safeguard and create attractive jobs Find the "right" people React to demographic change (secure experts and simplify access to further education)
Social responsibility:	Impacts on the population	Tackle conflicts of interests due to infrastructure expansion (e.g., passenger vs. goods trains) Avoid various emissions for (port) residents (e.g., port and railway noise)



Figure 4. Top ten environmental priorities of European ports (ESPO, 2020)

power connections that can supply barges with electricity from renewable energy sources at the quay-side. On analysis of the water quality, the waters of the city rivers can be contaminated with pollution directly from port activities and from ships. Therefore, the appropriate institution takes samples of the precipitation admitted to the port water areas. Previous analyses did not reveal any discharge of pollution or direct water pollution. The occurrence of pollution is mainly related to accidents.

Ports are usually spread across large areas and the development of ports threatens cities by occupying more areas. To prevent this, the port adopted a strategy to reclassify existing facilities instead of using new ones. At present, 37% of the port are natural habitat sites, including the port created nature reserve. Furthermore, the noise of the city area adjacent to the port also has a negative impact. But the conducted noise level measures show that it is constantly falling. Prevention of the negative effects of transport is evident in the use of efficient traffic routes, which are as quiet and climate friendly as possible. For example, the share of rail in hinterland traffic has increased by 5% in the last 10 years (from 41.3% to 46.4%), while the share of road traffic decreased from 56.0% to 50.5%. The impact of the port on adjacent areas is unavoidable. However, proper port management can reduce its negative effects. This section has described the factors with the greatest impact on the cities. Effective prevention of these effects can stimulate the implementation

and development of the concept of a green city in neighboring cities.

## Discussion

Ports and cities are intrinsically connected, as a result the port's impact on an adjacent city area is unavoidable. Even the current tendencies to develop ports in remote areas do not eliminate the interaction of these two systems. In general, port development stimulates GDP growth, increases employment, urban infrastructure development, and the overall enrichment of port cities. The ports of Bremen, as some of the first to develop and implement the green port concept (in 2009), have been diligently publishing their sustainability achievements. Long-term improvement of the adopted concept may constitute the basis for its transfer and development for the city. In summary, based on the above analysis of the green port, the most important factors affecting the city can be distinguished: air pollution, water pollution, noise, land use, and environmental protection. Important factors can also be an increase in employment, enrichment of society, development of city infrastructure and enrichment of the city, and the use of renewable energy sources.

## Conclusions

This paper analyses the green port concept of the Twin Ports in Bremen. Based on the given analysis,



specific factors of the port's impact on the city were identified in terms of sustainable development. Moreover, the relation between the port and the city during its development was briefly described. Factors such as air pollution, water pollution, land use, noise etc. are significant aspects to monitor when introducing the concept of a green city. However, taking into account the environmental issues, a negative impact of the port on the city can be observed. However, the green concept activities undertaken by the port so far not only improve economic and social factors but also environmental conditions for the city.

Summarizing the conducted research, it can be stated that the development of the port stimulates the growth of the city. Nevertheless, the effective introduction of the concept of sustainable development in the Port of Bremen, by improving important green concepts and the reduction of the harmful impact of the port, can stimulate and facilitate the implementation of this concept in the city so that it can become a green city. During the studies, there were restrictions on access to information, for example the latest data originates from 2020. The examined aspects are very developmental and the next stage may be to perform further in-depth research verifying more green port determinants and their impact on the development of green cities. Moreover, the implementation of this concept can be initiated.

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