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STRATEGIES AND APPROACH FOR SMART CITY–PORT ECOSYSTEMS DEVELOPMENT SUPPORTED BY THE INTERNET OF THINGS

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Abstract. The article presents a new contribution to understanding and building novel phenomena of Smart City–Port (SCP) ecosystems and new approaches for the use of new technical and technological findings. The main aim is to elaborate specific strategies SCP ecosystem can secure in the future and an approach for synchronised SCP development for adaption to growing urbanization, mobility and business development, where all stakeholders would take an active role. Based on analysed literature 19 strategies for common smart development of cities and ports are highlighted. The relatively new phenomena of the Internet of Things (IoT) or Internet of Everything (IoE) can simplify their achievement in SCP ecosystem. Moreover, the proposed 3 level approach for technological development of sensing, monitoring and managing data for spatial, transport, environmental and social policy is used on 2 Northern Adriatic cities and ports. The research provides actual analyses of SCP development at Koper (Slovenia) and Rijeka (Croatia), where the development of ports was carried in a completely different way. The article thus proposes a 2 phase approach to the development of SCP and can be used more widely in building a symbiosis of cities and their ports. Firstly, the need to fulfil the strategy from the set of 19 SCP development strategies should be identified and secondly by using a 3 level approach, with existing technological support a SCP environment can be set.

Keywords: smart city, port, smart city–port, transport, internet of things, development strategies.

Notations

DPM – data process model;
CC – cloud computing;
GDP – gross domestic product;
GPRS – general packet radio service;
GSM – global system for mobile;
ICT – information and communications technology;
IOC – intelligent operation systems;
IoE – internet of everything;
IoT – internet of things;
IT – information technology;
LV – limit values;
M2M – machine-to-machine;
RFID – radio frequency identification;
SC – smart city;
SCP – smart city–port;
SPM – smart parking management;
STM – smart traffic management;
WiMAX – worldwide interoperability for microwave access.

Introduction

Ports and cities are very connected systems, since large and economically strong cities were developed where important ports were established, with national or large regional functions. The opposite order occurred as well, as very often strong international ports were developed close to already developed urban and industrial basins.

Even when connected through some common elements, such as road or rail infrastructure, these 2 systems had in many cases independent lives and developments, especially where ports were in private hands. A closer relationship is established where the state or the city has the owner's share in the port or is somehow participating in the port authority's decisions. However, there are also cases where a city or state has operated a port but there was a disagreement about the development of port city ecosystems (e.g., in Rijeka) or where private stakeholders work closely with the city (e.g., Antwerp, Yokohama, Inchon, etc.).

City and port coexistence very often has positive impacts on the development of both systems, but develop-

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ment also brings some negative impacts. Positive effects are visible through the general development of new jobs, the creation of new supply chains that attract new logistics and transport companies, GDP growth, new investments in urban and suburban infrastructure (Fusco Girard 2013; Morel *et al.* 2013; Neirotti *et al.* 2014). The negative impacts are to some extent evident through an imbalanced development and quality of life. Namely, the number of people living in the cities is going to increase and according to a United Nations report (UN 2016) 55% of all people already live in urban zones and by 2030 this share will surpass 60%. Given foreseeable future economic growth, especially in some underdeveloped countries, the share will further increase to nearly 66% by 2050.

The trend of further urbanisation of cities and megacities will deliver multi-layered consequences and impacts on cities and systems existing in their vicinity. Ports or specialised terminals are one of such systems, where the intensity of urbanisation can have negative impacts on possible future development. These impacts can be expressed through higher traffic congestion and consequent limitation of inbound and outbound cargo flows and limitation of expansion for port logistics services. On the other hand, the development of a port or its specialized terminals will always have impacts on citizens and their life quality. The city will further tighten standards for air quality, noise pollution and light pollution as well. Moreover, the eventual expansion on the seaside is also very often only accepted with a certain resistance.

On this basis, we can argue that both systems require coordinated development, where the benefit of new technologies can be used on both sides. Zhuhadar *et al.* (2017) write that innovation through application of advance IT, analytics and systems that are introduced by SC can increase the quality of life in close urban areas. Okuya (2012) highlights the necessity of M2M connection and communication with big-data management to develop SC.

The initiatives for SCP development, where for instance the IoT or IoE is proposed or where a common nerve network (ICT network) between the port and city is developed, appear as potentially efficient guidelines for future development and coexistence. IoT represents a network of different sensors and systems that are connected with smart objects through the internet and exchange data in the network (Kopetz 2011; Gubbi *et al.* 2013). Iera *et al.* (2010) describe IoT as a group of objects that are interacting, in order to obtain common goals. In addition, new IT tools and approaches in smart port development can help port operators, drivers, carriers and the municipality to coordinate cargo flows, monitor and balance pollution, examine traffic bottlenecks and find new technological solutions to various and often new problems caused by growth itself (e.g., London, Hamburg, Singapore, Rotterdam, New York).

This study provides a 2 phase approach to the development of SCP ecosystem. Every city–port ecosystem can use different and needed strategies from the set of highlighted 19 SCP development strategies. Furthermore, by the introduction of elaborated 3 level approach a macro SCP environment can be set.

The study on Northern Adriatic ports and cities analyses whether the selected 2 ecosystems follow exposed strategies and whether they implemented different levels of smart functioning. The study follows 2 hypothesis:

- »» that the development and life-quality in the cities of Koper and Rijeka are very much influenced and to a certain degree also limited by their ports;
- »» that both cities and their ports could benefit from building a SCP ecosystem, where new technologies such as IoT might be used in sensing, monitoring and managing processes.

The study highlights actual limitations in better city–port coexistence, where both ecosystems have their plans for expansion and introduction of new contents. In the research the data where and how new technologies would improve city–port coexistence and what are the main bottlenecks for port–city interface introduction by the ports of Koper and Rijeka are analysed.

1. Literature basis and cognitions about SCP ecosystems and technological support

Ports have been part of scientific studies and analyses for centuries. Their influence on the national or regional economy, various related business concepts and technological developments are just some of key research areas that were highlighted in the past. Ports are very often analysed as independent systems, with economic interaction with systems from the surroundings or within supply chains (Bird 1963; Hoyle, Pinder 1992, Juhel 2001; Notteboom, Rodrigue 2005). With the new trends in globalisation, increase in world trade, complexity of supply chains and incresed urbanization and conurbation, new areas of research appear more oriented towards port–city or city–port sustainable development and coexistence. Norcliffe *et al.* (1996) in the late nineties analysed the evolution of symbiosis between the port and the city. Different stages in city–port links are described, where the city and the port can be very connected or economically and spatially disconnected. Hoyle (2000) sees the relationship between the city and the port as a cyclical development during the 20th century. The separate development was very much evident during 1960 and 1980, meanwhile after 1990 a strong focus and intent toward the renewal of port–city links has been present. Hall and Clark (2010) confirms that ports and cities are going through processes of connection and disconnection. Daamen (2007) shows that currently ports and cities have common goals, such as attracting new business, new supply chains and people. Fusco Girard (2013) points out that the strongest cities economically are in most cases port cities, such as Shanghai, Tianjin, Shenzen, New York, Tokyo, Singapore, etc. Their real GDP growth rate, GDP per capita and household annual consumption are higher compared to non-port cities. According to Neirotti *et al.*

(2014) port cities can benefit from higher GDP growth rate through easier investments in new technologies that are necessary for SC development.

Growing ports need new workforces and coastal cities are at the same time expanding (Morel *et al.* 2013). Although they have some common goals, which are certainly connected to the growth in different business areas, very often the community hinders the growth from the environmental and spatial view. This is ascertained by Wiegmans and Louw (2011) in their research of northern Atlantic ports and cities. Furthermore, Fusco Girard (2013) sees conflicts in producing and managing waste, dredging processes, navigation, etc., where local urban inhabitants suffer from negative impacts, while trade and industry stakeholders benefit from positive impacts.

Consequently, it can be predicted that cities support port activities, development and extension, but where and if possible rather outside the city area. Ports are therefore forced to expand on the landward side away from the city centre. To some extent, this hinders their berth subsystem development, which is directly connected with the sea side. Debrie and Raimbault (2016) state that cities prefer to develop recreation and tourism boating which is in conflict with freight activities. For this reason, ports very often search for new areas that are away from the city to build and develop new terminals for a longer period (Wiegmans, Louw 2011). Such development is usually more expensive and later also more difficult to manage, but limits the port's negative impacts on life in the city.

Perera *et al.* (2014), Jin *et al.* (2014), Zhuhadar *et al.* (2017) and Yang *et al.* (2018) highlight the advantages offered by new technologies for more efficient and coordinated development of the city and the port (Table 1). Witte *et al.* (2018) call for port–city innovation ecosystem development, enabling start-up companies to position themselves in the expanding field of port–city interface. The knowledge of IoT, smart ports and new technological solutions will have a more important impact on the development of SCP ecosystems in the future.

The actual literature in the field of SCP development predominantly highlights the needed policy for coordinated development of cities and ports. Moreover, the literature about the use of smart technologies in the cities and ports separately elaborate efficient development of new technologies in these 2 systems. On this basis, the article brings novelty by combining new knowledge of both research areas with special emphasis on setting widely defined strategies for SCP development and cross-sectional view where IoT can be already used as supporting technology. Moreover, based on technical cognitions an approach for building SCP is elaborated.

2. Synchronised SCP development

2.1. Setting common strategies and goals

Ports and cities are forced to find new ways of coexistence and to create a sustainable single ecosystem. Coordinated development should be based on understanding the separate development and needs of both systems. It is important to emphasize the aspect of smart technologies and processes. Cities are already following the guidelines for the use of new technologies that enable the development of SC. Angelidou (2014) highlights that different soft and hard infrastructural strategies have been implemented through SC projects globally. Although SC are developing, there is a lack of long-term strategies for SC

Table 1. Directions in SCP development

Reference	Directions and strategies
Hoyle (2000)	suggests the changing trend in city–port interaction development, where the symbiosis of coexistence gets new meaning
Daamen (2007)	posits that nowadays ports and cities promote the realization of common goals, such as attracting new business, that brings new supply chains and support city development
Hall, Clark (2010)	analyses processes of port disconnection from the city and the necessity of port–city reconnection due to the expansion needs of both systems
Wiegmans, Louw (2011)	investigates the new phase in port–city development, where the expansion needs and impacts of such development are highlighted
Fusco Girard (2013)	proposes a new circular economics model for port–cities areas, where economic, ecological and social elements are highlighted in a synergistic development of ports and cities
Morel *et al.* (2013)	analyses strategies of sustainable development and competitiveness of port–city systems, with special focus on environmental aspects, rational use of renewable energies and assessment of the interface
Perera *et al.* (2014)	proposes the potentiality of sensors and IoT implementation as a platform for SC development
Neirotti *et al.* (2014)	analyses trends in development of SC by highlighting six main domains and the associated sub-domains of SC deployment, in order to elaborate contextual variables
Witte *et al.* (2018)	proposes the basis for port–city innovation ecosystem development for facilitating start-ups development that can support better coexistence
Zhuhadar *et al.* (2017)	highlights the need for guided and coordinated performance of SC development and proposes the city's IOC
Yang *et al.* (2018)	analyses the use of sensors and smart infrastructure by ports and exposes potential IoT brings in managing smart ports

development (Dameri, Rosenthal-Sabroux 2014). Different studies expose 3 key areas of long-term sustainable urban development: economic, ecologic and social aspects of development (Daamen 2007; Fusco Girard 2013). Lombardi *et al.* (2012) analyse five clusters in establishing SC, such as smart economy, smart governance, smart living, smart environment and smart human capital. These elements were used also by Bakıcı *et al.* (2013) in the case of SC initiative for Barcelona city. Moreover, Neirotti *et al.* (2014) propose 6 broader areas of SC development, such as (1) transport and mobility, (2) natural resources and energy, (3) buildings and architecture, (4) quality of life, (5) economic aspect and (6) government. Each of these areas includes different fields that are necessary in everyday life of urban inhabitants and city as a system (Table 2).

The port, as an individual system that is mostly focused on higher economic results, also sets its own development goals that are nowadays oriented towards higher automation. Moreover, ports follow the development of new businesses, the establishment of new commercial ties, which influence the construction of new transport infrastructure, higher productivity, environmental sustainability and employee's satisfaction. In the forefront and highly ranked it is certainly an economic aspect of the business. On the other hand ports also play an important social role as they are directly involved in local or regional educational processes, they support regional or national cultural society, sport clubs, etc., through sponsorship or directly as donors. According to DTTL (2017) study, ports are undergoing the 4 generation of development, as the 1st generation is just a handling port; the 2nd is the industrial port and the 3rd generation ports have a strong focus on logistics and supply chain. The next or the 4th generation ports are those transforming themselves into SP.

In order to ensure harmonious development and coexistence, it is necessary to harmonize the priorities and guidelines for the development of both systems. Wiegmans and Louw (2011) specifically highlight the need to follow 3 basic development areas of port–city ecosystem: (1) spatial policy, (2) environmental policy and (3) transport policy. By adding the necessities to support social policies, as they are important for close coexistence of both systems, the 4 pillar SCP policy can be set (Figure 1). These 4 pillars represent a cross-section of common development orientations the city and port should agree upon.

Moreover, it is necessary to define specific strategies within these 4 pillars that both systems should develop with an aim of minimizing side effects on both sides. Based on actual literature – Daamen (2007), Wiegmans and Louw (2011), Lombardi *et al.* (2012), Fusco Girard (2013), Neirotti *et al.* (2014), Angelidou (2014) – strategy analysis of different highly developed cities and their global ports, 19 main strategies for synchronised SCP ecosystem are highlighted (Table 3).

The implementation of some strategic orientations can be accelerated and more effectively implemented by using modern technologies. The evolution of the findings of the rapidly developing IoT is largely covered by the implementation of data collection and big-data analysis. Solutions for SP are already implemented by some European ports, like Hamburg, Antwerp, and Rotterdam that are mostly oriented towards internal productivity increase, but they are beginning the development of their smart connections with stakeholders and the city as well.

Presented 4 pillars strategies are especially useful for a group of ports and cities that are:

- closely linked and sharing part of the common areas and infrastructure;
- the port has an important transport and trade function for the wider region (growth in the volume of freight, accommodating means of transport);
- the impacts of the port are clearly visible on the life quality of the population;
- it is difficult to redirect the port's activity to other peripheral locations outside the city (limited space);
- the port has an important role for the development of the city.

2.2. General approach for SCP ecosystem development

The proposed general approach for SCP ecosystem development is based on 3 level approach of developing sensing, monitoring, managing and data sharing activities. The *1st step* involves the activities of analysing the necessary sensors for the provision of permanent measurements (e.g., traffic congestion, air pollution, marine pollution, etc.), their optimal installation and operation for all 4 identified SCP development areas (Figure 2).

Table 2. Main areas and fields of SC development (source: summary of different research)

Main developing areas	Specific fields of development
Transport and mobility	daily migration of workers to/out of the city, internal public mobility, city freight logistics, infomobility, transit freight transport (port activity), transport infrastructure, green suprastructure
Natural resources and energy	exploring natural resources of energy (solar, water, air, heat), waste management, food production, reducing public lighting and water consumption
Buildings and architecture	general infrastructural development, maintenance, providing cultural heritage, new public buildings, land utilisation
Quality of life	public safety, limited all kinds of pollution, entertainment, social development, culture, green areas
Economic development	education, new business, innovation, new technologies
Government	e-administration support, transparency, new services, low-cost administration

Table 3. Main strategies for coordinated SCP ecosystem development (source: based on analysed literature)

Common developing areas	Strategies for common smart development
Spatial policy	– optimal use of the existing space in the use of the city and the port; – planning the use of additional areas for port expansion from coordinated perspective of common ecosystem; – synchronised and long-term content planning of new public spaces in the vicinity of the port in terms of eventual negative influences from the port; – withdrawing the port to the city's periphery
Environmental policy	– minimising air pollution in the city and generated by the port activities; – limiting light pollution – smart lighting (management) in the city and by the port; – minimising noise pollution generated by the port services and within the urban city areas; – coordinating waste management in the city and by the port; – coordinating water management of both systems; – minimising pollution level in the sea generated by the port/vessels and by the city's faecal waters
Transport policy	– managing optimal freight corridors; – optimisation of public transport; – improving and maintaining safety within city area (managing freight and public flows); – securing mobility of pedestrians and bicyclists; – smart managing of freight and public parking areas
Social policy	– improving and accelerating internal and external education processes; – preservation of sensitive areas around the port; – balanced sponsorship and donations according on ecosystem's long-term policy; – supporting preservation of cultural and historic heritage inside and outside the ecosystem

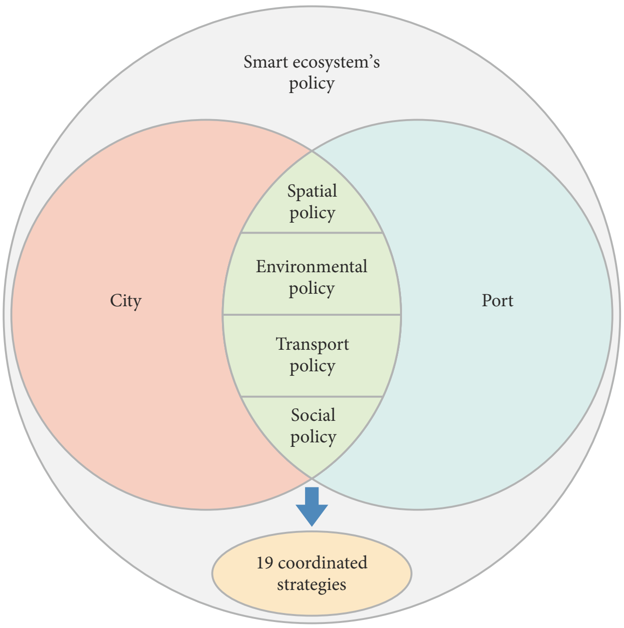

Figure 1. 4 pillars SCP policy for smart ecosystem development (source: based on analysed literature)

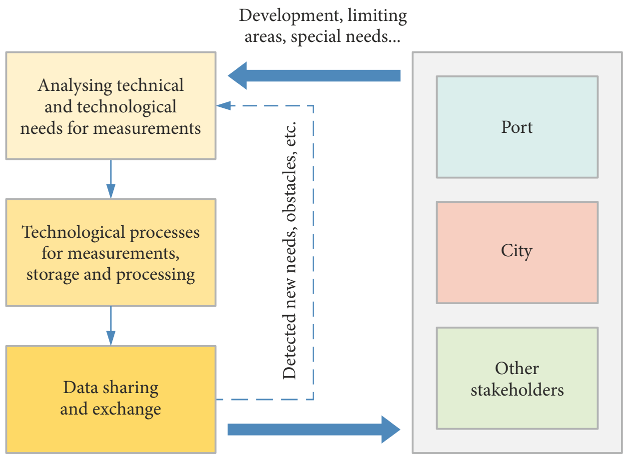

Figure 2. 3 step general approach for SCP development (source: prepared by authors)

The *2nd step* involves the technological processes of data measurements, their storage and processing. The *3rd step* represents the crucial phase of the SCP operation, since the processed data are exchanged with the stakeholders and used in the strategic, tactical and operational functioning of the port and the city.

SCP needs to develop mechanisms for the overall and long-term balanced functioning of the city–port ecosystem. The development of technological data capture processes, their processing and storage must be recognized from both sides, of the city and the port. Data sharing and exchanging processes must serve the city, port and other stakeholders.

2.3. New technologies and IoT as a platform for SCP

New technologies should simplify SCP ecosystem development. They should be introduced as quickly as possible on both sides, by the port authority or by terminal operators and by the cities. Perera *et al.* (2014) describe the potentiality of sensors and IoT as a widely used platform for SC development. They propose Sensing as a Service (SenaaS) model, with 4 conceptual layers: (1) sensors, (2) sensor publisher, (3) extended service provider and (4) sensor data consumer. Földes and Csiszár (2017) propose a model approach for city logistics concepts in smart cities that could be built on sensing and IoT. Okuya (2012) highlights the need for faster M2M communication development. Different technologies can be used for M2M system such as GSM/GPRS, Bluetooth, Wi-Fi, ZigBee, WiMax (Chamoso *et al.* 2018). In addition, autonomous machines (vehicles) will be widely used in smart cities of the future, thus smart sensing and communication will be of crucial significance for safety reasons and operational optimisation. Csiszár and Földes (2018) elaborated system's model for faster introduction of such technology in SC. In order to cover more and more areas of everyday city's functionalities, Zhuhadar *et al.* (2017) see the need for the establishment of a city's IOC, which guide and coordinate the performance of SC through M2M and big-data management. Such a central system provides the necessary support in monitoring and managing the growing business and social content. Chamoso *et al.* (2018) expose that the growing number of sensing objects and users can limit data transactions response speed. Consequently, they see the architecture solution in CC technology. Armbrust *et al.* (2010) expose that CC facilitates situation of peak demand and increasing data sharing that would be often the case in SC. Finally, emerging SC already use or are in project stage of implementation of different SC platforms, such as Sentilo, IBM Intelligent Operation Center, Smart-Santander, CitySDK, etc. (Chamoso *et al.* 2018).

From the point of view of SP development, IoT represents an important technological platform for future development as well. Sensors and smart infrastructure can be used by port and stakeholders for better transport services and at the same time for higher quality of life. Such connections can allow port operators to monitor actual productivity, pollution, and degree of safety (Yang *et al.* 2018). Kopetz (2011) shows that smart data and IoT are already widely used in transport and logistics processes by RFID technology. Increasing quantity of data about cargo and performed services are shared between different users to simplify logistics services within a supply chain. Consequently, ports must follow this trend, in order to prevent becoming a weak point in digitalised supply chains. Bauk *et al.* (2018) noted that RFID technology is used also by ports in internal processes of data exchange and for safety of workers.

It is important to elaborate which common development areas and strategies for ports and city systems can be covered by the digitalisation processes, where the use of IoT and big-data analyses, processed by IOC, present the main technological platform.

2.4. Technology support to SCP strategies

IoT can support the implementation of almost all presented strategies in Table 3. Just 2 strategies from spatial and social policies contain a specific content approach (withdrawing the port to the city's periphery, sponsorship and donations activities). Activities for optimal use of the existing space and for planning the use of additional areas for expansion or for the content planning of new public spaces in the vicinity of the port can be supported by sensing processes, data elaboration and sharing. Collected data about actual business activities and public activities in specific areas, the presence of protected animal species, all kinds of pollution generated by the port activities, etc., can be monitored, collected and elaborated for better spatial planning of a SCP ecosystem.

In addition, an IoT platform has the ability to collect and process data about air pollution, light pollution, noise pollution, water pollution, waste management and water management of both systems. By developing the DPM and by the use of IOC the data can be shared among different stakeholders, citizens and city administration offices for better coordination of traffic, human mobility, costs reduction, etc. Gharaibeh *et al.* (2017) write that some cities already adopted smart light management (Amsterdam, San Jose), pollution management (Boston), STM (New York, Louisville). Siemens developed a pollution-forecasting tool that has been installed in London. Moreover, IBM elaborated its solution for pollution management in Beijing.

The third pillar dealing with transport policy is very important as ports generate traffic flows and indirectly a certain amount of human flow. At the same time, an inevitable trend of increasing populations in cities is going to increase the pressure of every-day mobility. Consequently, mega cities will suffer from traffic congestion, lack of parking space, eventual traffic safety decrease, etc. An IoT platform can offer productive solutions in real-time managing optimal freight corridors, for optimised routing of public transport and better and safer mobility of pedestrians and bicyclists. This can be achieved by combining and processing different variables related to real-time data and data models that are supplied by DPM. Solutions such as informing truck drivers about congested roads, traffic accidents, closed terminals due to weather conditions, a changed traffic regime due to severe pollution, and so on, can prevent further congestion and eventual accidents. Cisco, IBM, Siemens corporations developed solution for smart traffic management for cities and were tested in US, Asia and Europe. In addition, the city of Dallas picked Ericsson corporation for STM solution. The cities of Amsterdam and Barcelona are also introducing STM and SPM.

The last pillar of social policy can be also supported by an IoT platform. Special fields like preservation of sensitive areas around the port or cultural and historic heritage can benefit from data collection, sharing and processing. The collection of data about the influence of vibration and noise on the stability of old buildings and infrastructure can secure variables affecting prevention decisions. Furthermore, data collection in sensitive areas such as closed and limited natural ecosystems and animals can be the basis of future quantitative and qualitative decisions on protectionism. IoT can be used in education processes, as students, schools and faculties or other research institutions can obtain certain predefined data directly (through CC platform access), enabling them to study the data and to build further models for IoT implementation.

3. Possibilities for SCP development at Koper and Rijeka

3.1. Basis for SCP ecosystem

The proposed 4 pillars SCP policy and main strategies for smart ecosystem development were elaborated on 2 Northern Adriatic cities and their ports. Koper and Rijeka are 2 coastal towns that are rich in history. The towns were founded more than 2 thousand years ago in the Northern Adriatic. Both cities have an important economic and transport role for their national economies, as well as important transport roles in the western Balkan and Central Europe. The development of ports in Koper and Rijeka dates back to a more recent period. The development of the port in Rijeka originated at the beginning of the 18th century, while the port of Koper was built after the Second World War.

The starting point for the creation and positioning of the port determines the possibility of expanding the port and coexistence with the city. The Koper port extends to the territory of 2 municipalities – Koper and Ankaran. The south area of the port is directly connected with a defined historic city centre (Figure 3). In total, Koper port uses 453 ha. Of this, 274 ha are land area. It has 3282 m of coastline, where work is carried out on 28 berths that are used by 12 specialised terminals. For cargo storage 109 ha of open storage facilities are used, meanwhile 50.7 ha of closed special purpose warehouses are used for logistical activities.

The Port of Rijeka extends to 5 different locations in the Rijeka basin, Susak, Bakar, Rasa and Omisalj. The Rijeka basin and Susak, and to some extent also Bakar play an important role in the establishment of a smart ecosystem with the city of Rijeka, as the port on its northern side directly touches the old town centre (Figure 4). The land area measures 50 ha, but the total length of coastline exceeds 6000 m. The port does not have the possibility of expansion into the mainland, so its expansion can only be carried out on the seaside. Port of Koper has no such limited spatial conditions. The southern part is limited by the city of Koper and on the northern part by the city Ankaran, but still there is much free land space on the eastern side. The city of Koper also plans to utilise these areas for city's further industrial expansion.

Both ports have an important impact on the environmental and transport aspects of the city. Pollution of noise and light, air pollution and pollution of the sea have direct impacts on the quality of life in a single ecosystem. This is especially evident in the case of stronger southern winds at Rijeka and during the strong north wind at Koper. The growth in the volume of transport activities affects the increased incoming and outgoing freight flows, which must transit the city centre area by using urban roads. Both cities encounter heavy traffic and frequent congestion, which significantly affects the mobility of urban people.

Both ports and cities are thus classified as city–port ecosystems that are closely linked and sharing part of the common areas and infrastructure, and it is difficult to redirect the port's activity to other peripheral locations outside the city due to the limited available space. In both cases, the port has an important transport and trade function for the wider region that influences the throughput growth, thus the port also has an important role for the development of the city. Moreover, the impacts of the port are clearly visible on the life quality of the population.

3.2. Spatial policy

The development of SCP ecosystems in Koper and Rijeka will face limitations in spatial planning. The pressure is even more evident in Rijeka, due to space limitations and possibilities of port expansion being only in the direction of sea. Consequently, SCP system has to elaborate an optimal use of the existing space. The city can expand its area on the northern side, where the limitations are foreseen just in longer connections with the main city area that is also a commercial area of the city. On the other hand, SP at Rijeka and Koper must develop smart planning approach for the use of additional areas for its expansion with an aim to evaluate further impacts on everyday life in SC, such as increasing freight flow, increasing pollution and influencing safety. Higher automation and use of new green technologies can prevent a linear increase of these negative impacts.

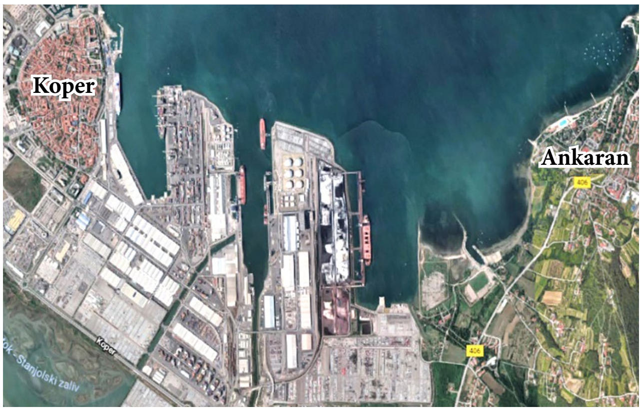

Figure 3. Port of Koper and the cities of Koper and Ankaran (*https://www.google.com/maps*)

Figure 4. Port of Rijeka and the city of Rijeka (*https://www.google.com/maps*)

Moreover, SC of Koper and Rijeka must use smart approaches in content planning of new public spaces in the vicinity of both ports. Using sensors and IoT or IOC for pre-analyses can support better decisions regarding whether to use some specific areas for industrial expansion, entertainment, green areas, building new roads, etc. By developing new content and building new infrastructure it is necessary to plan smart infrastructural installations for subsequent easier, efficient and lower cost operations of the SCP system.

3.3. Environmental policy

The ports at Koper and Rijeka already measure air, water, noise and sediment pollution in most exposed areas. The port of Rijeka provides noise level measurement at 6 points, sea quality measuring at 7 points, condition of seabed sediment at 6 points and one measuring point for air pollution. The results show that noise levels at all measuring points are between 48.4…74.7 dB, with the highest values during the day (Sušac *et al.* 2017). The air quality measurement provides data about concentrations of sulphur dioxide, nitrogen oxides and particulate matter PM_{10}. Sea quality and wastewater quality results performed by Darh 2 d.o.o. (*http://www.darh2.hr*) show that some LV are exceeded, that can be connected also to construction works. With further port expansion such circumstances can be foreseen also for the future.

The port of Koper provides air quality measurement of PM_{10} at 3 points, in the southern part near the city of Koper, on the northern side, close to Ankaran, and on the eastern side in the direction of Bertoki. Noise level measurement is also provided at 3 points, covering the same area as the air quality measuring points. The highest values of noise (68 dB) are measured in the southern area during the day, close to LV, affecting quality of life in the city of Koper (Luka Koper 2016). The quality of sea is measured at 3 points inside the port and by one buoy beyond port basins. The 4 measuring points are used for detection of possible spills of petroleum products.

Both ports already use installed sensors for measuring the main environmental impacts port can have on the city. Some of the measured results, such as noise and air pollution, are published on dedicated web pages, enabling citizens to make informed decision to some degree regarding life-style choices. Nevertheless, new technologies and IoT can secure wider use of these data in a SCP system, such as:

- smarter traffic planning and regulation in the port and in the city;
- advising inhabitants about exceeded LV through mobile devices or smart vehicles for real-time decisions in everyday life activities;
- instant advising of port operation departments for real-time technological improvements;
- measuring and managing waste by introduction of smart containers inside the port area and around the city area.

3.4. Transport policy

Transport policy in a SCP system at Koper and Rijeka should be based on building new traffic infrastructure that should allow easier and efficient cargo flows to and from the ports. The city of Rijeka is facing more limitations due to an already densely populated urban area behind the port area. On the other hand, Koper has potential for efficient traffic regulation, by building the new entrance point for road vehicles in the direction of the highway, where the state and the municipality of Koper should provide an adequate road connection between these 2 elements.

The ports and the cities should install traffic measurement points in heavy congested areas to measure traffic flows, noise and pollution, supervising traffic accidents and optimising traffic regulation. IoT should simplify data exchange and informing all the stakeholders promptly. Moreover, optimal freight corridors and optimisation of public transport can be reached, as the freight and public traffic peak time is the same, from 7:00 to 17:00 h.

IoT can also provide the basis for efficient managing of parking areas for trucks as well for urban people, traveling by own cars. Real-time data provided by the sensors, IoT and IOC can be used by pedestrians and bicyclists, which number is constantly increasing in Koper and Rijeka, due to increasing problems of traffic congestion. All these measures should also have positive impacts on increasing safety level in traffic.

3.5. Social policy

The social policy is the 4th pillar in SCP development. The area of smart ecosystem development is very large; thus the study limits observation to preservation of sensitive areas around the port, supporting preservation of cultural and historic heritage, and for educational processes, where new technologies and new cognitions about smart infrastructure can support better and harmonised port–city coexistence.

Both ports are forced to manage processes that are not related to their main business, such as preservation of sensitive areas around the port. The port of Koper is actively involved in the preservation of the nature reserve Škocjanski zatok. This area is important in order to preserve green city areas and for balanced development of urban city infrastructure. The measurements regarding the influence of light pollution, noise pollution and air pollution on protected species of animals and exchanging data with researchers from Škocjanski zatok can provide the basis for long-term coexistence. Close to the city of Rijeka is a protected natural area called Rječina, just 10 km from the port area. The increasing development of Rijeka port might have some impacts on this area, thus preservation activities by SCP are foreseen.

The preservation of cultural and historic heritage is the second important element in managing social policy in the SCP ecosystems at Koper and Rijeka. Both cities have long and rich histories and their old city centres require special preservation care. The impacts produced by the port activities, such as vibration and air pollution, have negative consequences on old buildings and other infrastructural influence. These fields are not covered by measurements and monitoring systems so far, thus the introduction of sensing and IoT can become the platform for effective preservation activities.

In addition, smart infrastructure, sensors, sensing and big-data management obtained in a widely organized SCP system can be exchanged with faculties and other research institutions for educational purposes and for modelling new paradigms in quite new phenomena of IoT and IoE. Direct data analyses by these institutions can lead to faster introduction of new cognitions on all defined segments represented by the 4 main developing pillars of a SCP ecosystem.

4. Results – obstacles and limiting factors

An analysis of the actual status of defined strategies for SCP ecosystems at Koper and Rijeka was performed. The scale −1, 0 and 1 was used to rate the status of each strategy. −1 means that no basis of sensing, monitoring and managing was detected. 0 means that sensing and monitoring activities are detected but the next step of managing and sharing data is missing. A level of 1 is used where the strategies are supported by sensing, monitoring, managing and sharing of data, where IoT is used. The minimum rating is −17 points and maximum +17. The middle result of 0 points shows that the city–port ecosystem developed the basis of SCP development, but in most cases the implementation of managing and sharing processes is missing. This gap can be covered by IoT, IoE and IOC development and permanent use.

The data presented in Table 4 show that both ecosystems have only partially developed a base that can be used for the development of SCP systems. Both city–port systems developed means of measuring environmental impacts from port and city activities. However, the obtained data are not managed and widely shared for betterment of the everyday life of citizens. Cities and ports also measure the use of truck and car parking areas. These data are presently communicated on the highways (e.g., Senožeče–Koper or Dekani–Koper) and in the cities on special information boards; but IoT could secure direct data sharing with truck and car users via portable devices and smart cars. The other strategies do not have an actual basis in sensing processes or in monitoring processes. Consequently, the given score is −1.

Both cities obtained the same score of −9 points. The result suggests a currently low level of SCP. Consequently, both analysed cities will have to invest in sensing technology and data processing technology in several fields required for successful SCP development. Foreseen obstacles are funding, technological development, technical knowledge, interest from businesses and other stakeholders, small number of inhabitants and actual freight volume, awareness of potential better city life and future maintenance costs.

Moreover, the main limiting factor is the development of joint initiative among the government, city administration and port stakeholders. All parties should take an active role in SCP ecosystem development, with an aim to elaborate a feasible medium and long-term strategic action plan (new public infrastructure and traffic corridors, new living areas, future green areas, etc.). Among others, such a plan should incorporate the implementation of described smart technologies and platforms.

Table 4. Analysis of proposed strategies for SCP supported by IoT in Koper and Rijeka (source: prepared by authors)

Strategies for SCP development by using IoT	Rate Koper			Rate Rijeka		
	−1	0	1	−1	0	1
Optimal use of the existing space in the use of the city and the port	×			×		
Planning the use of additional areas for port's expansion	×			×		
The content planning of new public spaces in the vicinity of the port, in terms of eventual negative influences from the port		×			×	
Air pollution in the city and generated by the port activities		×			×	
Light pollution and management – smart lighting in the city and by the port		×			×	
Noise pollution generated by the port services and within the urban city areas		×			×	
Waste management in the city and by the port		×			×	
Water management of both systems		×			×	
Pollution level in the sea generated by the port/vessels and by the city's faecal waters		×			×	
Managing optimal freight corridors	×			×		
Optimisation of public transport	×			×		
Safety within city area (managing freight and public flows)	×			×		
Mobility of pedestrians and bicyclists	×			×		
Managing parking areas		×			×	
Education processes	×			×		
Preservation of sensitive areas around the port	×			×		
Supporting preservation of cultural and historic heritage	×			×		

Conclusions

The study bring new view on fast developing phenomena of SCP development. Present researches are more focused on SC or SP development. The article thus brings contribution in processes of contemporary and sustainable building of SCP eco system. The 2 step approach in developing SCP ecosystem is presented. 1st step – the city, port management and the state must analyse and select a group of strategies for medium and long-term development of the ecosystem; a general approach for SCP development must be elaborated, by analysing the necessary technical and technological needs for sensing and data collection. The 2nd step involves the development of processes of data measurements, their storage and processing. Finally, the strategy of building SCP ecosystem must contain an approach for data exchange and sharing with all the stakeholders.

The study on 2 Northern Adriatic city–port ecosystems confirms that the development and life quality in both cities are influenced and to a certain degree limited by their ports, through transport activities, environmental impacts, spatial and social policy. The second hypothesis that both cities and their ports could benefit from building a SCP ecosystem, where new technologies as IoT might be used in sensing, monitoring and managing processes is also confirmed. Namely, different fields of common sustainable development are highlighted that could be more rapidly managed by the use of IoT.

The study proves rapid technological development in the field of sensing and data management in the development of modern cities. At the same time, technologies for the development of smart ports are being developed. Similar studies are needed to highlight the simultaneous and coordinated development of both systems in a unified and sustainable ecosystem.

Further research on the possibilities and needs of the development of SCP ecosystems in the Eastern Adriatic area will focus on the development of a set of strategies and technical insights that can be used by ports and cities with a long and rich history such as Split, Dubrovnik, Bar, etc.

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