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Marine Spatial Data Infrastructure Development Framework: Croatia Case Study

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Abstract: Spatial data infrastructure (SDI) related to marine spatial data is known as marine SDI (MSDI). In this paper, we determine data themes under the MSDI in the order of usefulness and efficiency. The purpose is to streamline and support the prioritisation of data to be further implemented in the MSDI. This is conceptualised using the logic of decision support systems and a multi-criteria analysis approach that integrates components such as data, stakeholders, and users through multi-criteria methods for priority ranking. This research proposes an MSDI development concept and is validated using the Croatian MSDI case.

Keywords: marine spatial data infrastructure (MSDI); geoinformation science (GISs); planning; development

1. Introduction

The term "infrastructure" implies something that is fundamental or basic. Spatial data infrastructure (SDI) is the foundation of human activities relating to spatial data on different levels [1,2]. Effective spatial data management reflects the progress of society, so there is a natural need for the organization of data in the form of infrastructure. If we asked the experts who deal with spatial data how they define SDI, we would obtain different answers according to the context in which they use SDI or spatial data. There are different definitions that we can find in the literature. Wytzisk and Sliwinski [3] stated that a conference on "Emerging Global Spatial Data Infrastructure" held in Bonn in 1996 was a turning point in the development of the concept of SDI and the raising of awareness in professionals. In the SDI Cookbook [4], Nebert defines SDI as a concept of supporting the environment that provides access to spatial data using standard practices, protocols, and specifications. In [5,6], SDI is seen as a tool to ensure an environment in which all stakeholders (users and producers of spatial data) can collaborate and make the most of technology in a cost-effective manner to better achieve their objectives.

Expansion of the term SDI [7,8] to marine SDI (MSDI) began in 2008, stating that it is a framework that provides the integrated management of spatial data and information in the marine (maritime) environment, covering processes such as technology, policy, standards, data, people, and organisations. Emerging challenges such as the lack of operational objective data access and stakeholder involvement are described in [9,10] through a generic framework for the implementation of ecosystem-based marine management. They also mentioned the lack of communication between MSDI stakeholders and missing data operational procedures (themes, datasets, formats, and maintenance). The MSDI is recognised as an important resource for improving resource management and decision-making in both marine and land environments.

In [11], complexity is mentioned as the number one problem for understanding SDI: "SDIs are complex because they are dynamic like other socio-technical assemblies and result from ongoing negotiations and alignments between heterogeneous actors". As a solution, Erik de Man suggested institutionalisation of SDI as a unifying concept towards the effectiveness and sustainability of SDI initiatives, while recognising their complexities. In this way, the numerous conflicting views of different stakeholders can be avoided by anticipating different future MSDI needs. These conflicts emerge because—according to the GSDI "cookbook" [4]—SDI provides a start for the discovery, evaluation, and application of spatial data on all levels of government, the commercial sector, the non-profit sector, academia, and by citizens in general. SDI complexity is further mentioned in the context of the multi-view framework [12], as complex adaptive systems [13], and for the development of the next generation of SDI with linked data [14]; they all highlight the need for development coordination in different aspects.

In [15,16], SDI is exposed as an integration of a number of components to create a platform that enables all stakeholders to access, share, and use spatial data efficiently. They propose multi-actor multi-criteria analysis (MAMCA), a methodological framework of SDI development which has been applied to the SDI in Flanders (Belgium). The results of the study show that the next step in SDI development for Flanders could be the integration of private players and utility companies, thereby creating mutually beneficial relations.

Handling the large amounts of data related to spatial information in the future is unimaginable without the integration of a big data concept with well-established and well-managed SDI [17]. Keeping in mind the ever-increasing amounts of spatial data (as a whole or within just one data theme), it is easy to conclude that the planning of even a single thematic SDI must be conducted. The plan must cover the inclusion of all identified spatial data themes off a single thematic data theme, which are implemented in defined phases. In this research, different datasets are organised in data themes.

The quality of MSDI development will directly affect the quality of decision-making in the management of coastal areas due to the improved distribution of data, better data quality, information access, etc. Considerable attention should be paid to the development phases of establishing the MSDI. This paper focuses on the decision-making processes that occur during the drafting process of the development of the MSDI.

In practice, the planning exercise for MSDI development would define needed activities. To be more specific, planning would determine the dynamics of individual data themes in order to maximise the usefulness of the MSDI during the process of development and maintenance. The principles used to rank priority data themes for inclusion in the MSDI can be used later for prioritising updates and adding new data themes. Certainly, the objective is to involve data from which users will benefit the most, in accordance with the availability of other resources. MSDI is multidisciplinary, so this concept is a first step towards developing this complex model. After identifying the stakeholders and ranking the data themes, we include other aspects, such as the degree of institutional involvement, access, privileges and data custodianship, and data distribution and usage through the geoportal.

The high financial expenditure required for MSDI development and the limited available resources also contribute to the complexity, hence the need to define priorities. The need for good-quality priorities in the realisation of MSDI establishment and development projects is characterised as a poorly structured problem that we intend to solve by designing a planning support concept (PSC) to develop the MSDI. Good-quality priorities is an expression for deliverable/result of prioritisation process which considers all relevant aspects of the analysed problem, and provides more than just an ordinal scale of analysed actions. It also provides better insight into their mutual relationships in the context of the achievement of a predefined goal. For the purpose of this research, the authors designed a planning support concept engaged through the multi-criteria method PROMETHEE (Preference Ranking Organisation MeTHod for Enrichment Evaluations) that proved to be useful in dealing with similar poorly-structured problems. The research also seeks to identify relevant stakeholders and how to include them in the process of forming the MSDI and to classify data by themes. Its goal is to establish a more efficient and effective MSDI.

2. Methods

The proposed planning support concept is a system that belongs to an open-type system in accordance with the preferences of general systems theory [18]. According to the Oxford living dictionary [19], concept is used more for planning (especially new ideas and inventions). The proposed concept can be applied to the developmental planning of any other thematic SDI. The implementation of the concept is demonstrated through a case study of MSDI planning in Croatia.

The proposed concept facilitates the inclusion of and mutual interaction among all stakeholders during the planning process. By including views of different stakeholders in the planning phase, it is possible to minimise the problems that typically occur during MSDI development and later on in the process. The main issues relate to the inclusion of a large number of stakeholders with different views and needs relating to the development and future use of the MSDI.

We propose a solution in the form of a PSC for planning and using MSDI. Therefore, when designing the concept, approaches based on the key determinants of decision support systems and multi-criteria analysis are used. A similar approach can be found in the literature [20–22], in which several different decision support systems and concepts are developed based on a multi-criteria approach. These were helpful in creating the new and useful planning support concept presented in this paper, which achieves greater utility for a large number of stakeholders with a quality approach to MSDI planning.

Particular attention should be paid to identifying relevant data and to setting priorities for their inclusion in the MSDI. It is impossible to include all at once, because of the comprehensive and multiple data/service needs of stakeholders. They should be included by the level of their usefulness, taking into account the abovementioned needs/goals of all stakeholders. Therefore, the data should be classified into representative themes to determine priorities for inclusion in future MSDI. There should be a set of criteria to determine the usefulness of data. All of the criteria within a set are not equally important to stakeholders, and the opinions of all stakeholders about their importance must be considered. Therefore, the methods of multi-criteria priority ranking are embedded in the proposed PSC.

When starting to use this concept, the purpose of the future MSDI must be determined, meaning the study problem/area must be defined. In our case, it is MSDI and SDI that contain spatial data relevant for sea and coastal zone management.

Below is the architecture of the proposed concept based on the inclusion of a greater number of stakeholders in the complex multi-criteria MSDI planning process; i.e., the usefulness of the data for all stakeholders. Almost all of the stakeholders are also data producers. With this kind of planning, we want to maximise MSDI operation in all development phases. Each phase is characterised by more data themes included in the MSDI, meaning that all identified types of spatial data are still not included. The concept can be applied after the establishment of MSDI, since the data needs and the way in which they are used are variable.

Figure 1 shows the architecture of a generic planning support concept to develop MSDI. The concept is executed through three phases. The first phase (definition of study problem) involves the design of a questionnaire to identify relevant data and data classification. The second phase (priority ranking) involves comparing and ranking data themes, and the third phase involves the definition of the MSDI development plan.

The first phase comprises several actions, with some performed in parallel. Execution of the concept starts with an analysis of the current state of the MSDI, followed by three parallel actions: identification and organisation of stakeholders, identification of relevant data, and determination of goals. Organised stakeholders (divided into several characteristic groups) are involved in determining goals by establishing a goal tree, as well as identifying relevant data. The goal tree is a concept which provides a graphical representation of the reduction of problems (or goals) to sub-problems (or sub-goals/objectives) in a hierarchical structure, and it was presented by Peter Drucker's philosophy of management by objectives (MBO) [23]. Jajac et al. [24] and Bitunjac et al. [25] in their papers discuss the establishment of goal hierarchy structures in the form of a goal tree. They concluded that the establishment of such a goal hierarchy structure provides a better understanding of interrelations between the main goal and generated objectives, as well as between objectives and their sub-objectives, etc., thus ensuring a higher quality of the objective generation process [24,25].

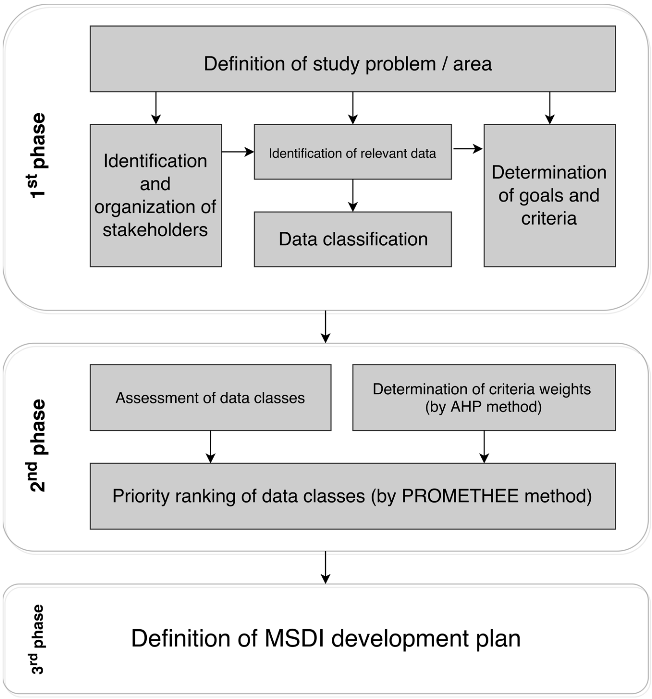

Figure 1. Architecture of the planning support concept to planning marine spatial data infrastructure (MSDI) development. AHP: analytic hierarchy process; PROMETHEE: preference ranking organisation method for enrichment evaluations.

In our case, the main goal is divided into objectives. Objectives were divided into sub-objectives that were used as criteria in further phases of PSC realisation.

A unique questionnaire was designed to identify relevant data in accordance with the defined goals. Identified data were classified into data themes after the execution of all three abovementioned actions. The first phase was complete after executing all of the abovementioned actions, and it stands as an input to the second phase.

The second phase comprises two parallel actions followed by a comparison of data themes and their priority ranking. The first action of the second phase deals with the assessment of data according to the results of the questionnaire analysis. Its parallel action refers to the determination of criteria weights by the analytic hierarchy process (AHP). Results of both parallel actions are inputs for comparison and priority ranking by the preference ranking organisation method for enrichment evaluations (PROMETHEE). According to [26], this outranking method provides a complete ranking of the alternatives from best to worst. The analytical hierarchy process from [26] "is probably the best known and most widely used multi-criteria analysis (MCA) approach". The AHP method is selected for inclusion within the proposed PSC because of the positive experience of the authors in the application of this method (as a user-friendly method for non-expert users) in resolving similar problems dealing with multiple stakeholders. Except for the abovementioned, the decision of the authors regarding the selection of the AHP method as an appropriate one can be supported by the findings of [26] regarding its compatibility with the PROMETHEE method (another multi-criteria method used within the proposed PSC) and by following references. The analytical hierarchy process—developed by Saaty and Erdener in the 1970s [27]—is a multi-criteria decision-making approach, and it has attracted the interest of many researchers because of the nice mathematical properties of the method and the fact that the required input data are easy to obtain [28]. The multi-criteria AHP method was used to evaluate the weightings for each criterion defined in relation to the overall project objective. It enabled the decision-makers to visualize the impact of each criterion on the final result [29]. It is based on three principles, namely: (1) construction of a hierarchy; (2) priority setting; and (3) logical consistency. The ranking list of data themes becomes the input for the third phase.

The third phase—"Definition of the MSDI development plan"—results in a definition of the plan according to the ranking list from the previous phase, which stands as a high-quality basis for decision-making. The development plan is formed in accordance with the priorities for implementation between identified data themes and the resources available to those responsible for MSDI development.

Therefore, the foregoing considerations and Figure 1 explain the general architecture for the supporting processes related to the planning and development of the MSDI. In addition, Figure 1 illustrates the modes of stakeholder participation in the improvement of the planning process. Their participation ensures better transparency in planning and prepares stakeholders to accept future activities related to the implementation of the MSDI development plan; i.e., development will be much easier. Each subsequent development phase (a short-term development plan for the next investment cycle that consists of several data themes included in the MSDI) can be determined by repeating the aforementioned procedure. All short-term implementation plans provided by the presented concept form the overall development plan. This approach ensures the actuality of each development phase of the MSDI development and of the MSDI as a whole. The multidisciplinary approach is also necessary because we take a general approach to the MSDI design project, which allows the stakeholders to adapt to continuous social and economic changes and on demands placed upon them by the data framework, and it is in accordance with [11] "institutionalisation of SDI" theory.

3. Results

This research focuses on the development of a planning support concept with special emphasis on the development of MSDI in the Republic of Croatia. Using the proposed framework, it can be used to avoid many potential weaknesses in developing MSDI.

The Hydrographic Office plays a central role in the development of the marine components of all SDIs. According to [30], "The Hydrographic Office (HO) is an important part of the National Spatial Data Infrastructure (NSDI) and, of course, the International Hydrographic Organization (IHO) has an important role to play in coordinating the requirements and demands for data collection, interoperability, dissemination, access, standards, security, pricing policy, and possible funding models". The Republic of Croatia is no exception. The Hydrographic Institute of the Republic of Croatia (HIRC) plays a major role in the development of MSDI in Croatia.

Currently, that development involves merging information concerning the field's coastal engineering, hydrography and surveying, protection of the marine environment, regional planning, and coastal research. This undertaking is based on a series of regulations from which specifications and courses of action derive. To efficiently and effectively develop Croatian MSDI, the HIRC and other providers of marine data need to build a planning support concept and develop models to support common workflows in marine applications.

3.1. The First Phase: Definition of Study Problem

The inclusion of relevant stakeholders in establishing MSDI begins in this first phase. The direct function of their inclusion is two-fold. Primarily, it supports the ability to predict current and future user needs, and thereby optimises the MSDI design theme and realisation. Secondly, it allows the introduction of stakeholders to the process of establishment, content, organisational, and expected utility of a thematic MSDI before putting it into operation.

3.1.1. Identification and Organisation of Stakeholders

Starting from the assumption that MSDI does not exist in Croatia, we first contacted an HIRC legal representative for information regarding potential stakeholders. He gave us a list of ten experts that use marine spatial data in their work. Stakeholder identification was then extended based on a detailed literature review and expert meetings, through interviews with experts in the HIRC and several experts that use spatial marine data in their work (an oceanographer, a hydrographer, hydrotechnic engineers, a geophysicist, and an economist). Almost all of the stakeholders are also data producers. The identified stakeholders are also users; for example, one significant data provider—the Institute of Oceanography and Fisheries (IOF)—frequently uses data from the HIRC or Ministry of Maritime affairs, Transport and Infrastructure, and vice versa.

Identified stakeholders in Croatian MSDI are organised into the following seven groups:

- Government (Ministry of Maritime Affairs, Transport and Infrastructure; Ministry of Defence; Ministry of Tourism; Ministry of Environmental and Nature Protection; Ministry of Construction and Physical Planning);
- State administration (State Geodetic Administration);
- Academy (Faculty of Civil Engineering—Zagreb, Split, Rijeka and Osijek, University Departments of Marine Study, Faculty of Maritime Studies);
- Institutes (HIRC, IOF, Institute for Marine and Coastal Research);
- Private sector;
- Agencies, projects, and NGOs; and
- Other users (end users like divers, fisherman, sailors, and maritime trainers).

In interviews with experts, in addition to identifying users, we also constructed a series of questions and other prompts for use in future research.

3.1.2. Determination of Goals and Criteria

By defining the main goal (MSDI development design), the process of constructing a goal tree was initiated. Supporting objectives and sub-objectives at both hierarchy levels (two objectives at the first hierarchy level and seven sub-objectives at the second hierarchy level, further referred to as "criteria") were generated/defined by group decision-making during brainstorming sessions with all stakeholder groups. Two supporting objectives of the main goal are defined as follows: maximisation of data availability and maximisation of data relevance. These two objectives form the first hierarchy level of a goal tree, presenting two important issues in the development of MSDI data and its usage. Analogously, sub-objectives are generated/defined by the division of these two objectives. Maximisation of data availability is divided into four sub-objectives (C1–C4), and maximisation of data distribution is divided into three sub-objectives (C5–C7), as shown in Figure 2. These seven sub-objectives indirectly support the achievement of the main goal because they support the achievement of objectives which support achievement of the main goal. It should be emphasized that each sub-objective supports achievement of only one objective (from which it is derived-generated/defined).

After MSDI development has commenced, there is a constant need to update data themes using different types of data and by collecting new types of data; therefore, the design of MSDI should maximise usefulness for users during and after the development phases. Thus, the second level of the goal tree consists of seven objectives (Table 1).

The bi-level goal tree is depicted in Figure 2. Each objective within the goal tree is determined taking into account a high level of legal background, spatial data standards, and initiatives. The Croatian MSDI case is subject to the European Spatial Data Infrastructure (ESDI)'s INSPIRE directive which has been translated in Croatian Law on NSDI. The INSPIRE directive recommends using ISO Geographic information/geomatics and OGC standards. Croatia is also member of IHO; therefore, it follows IHO initiatives.

In addition to the requirements which the INSPIRE directive imposes on Member States, the Directive also offers support for SDI development, application schemas, and data models. The INSPIRE directive becomes the basic framework for the further development of models that depend on specific customer requirements.

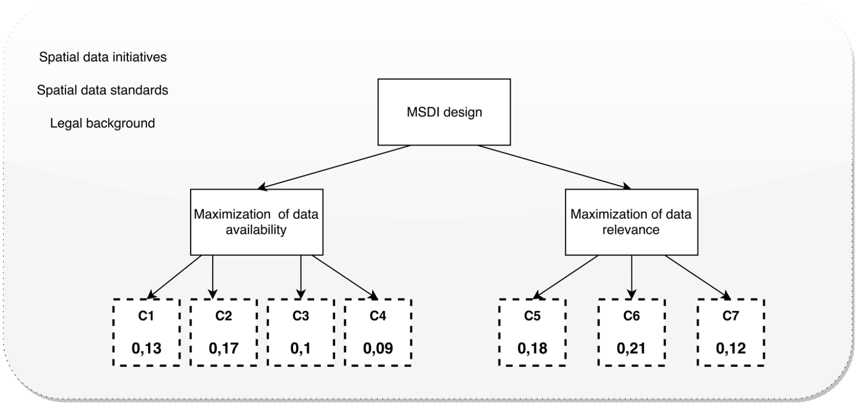

Figure 2. Goal tree for the Croatian MSDI case.

The last hierarchy level of the presented goal tree (Figure 2) comprises immutable and measurable sub-objectives to adopt as criteria sets for the evaluation of alternative solutions. The first column of Table 1 provides labels of criteria (which will be used further in the paper instead of full criteria names in order to facilitate their easier quoting), full names of criteria are shown within the second column. The third column provides a short description of each criterion and of its assessment technique. Assessment technique is the manner in which assessment is provided and expressed by that particular criterion (i.e., assessment according to C1 is provided as a weighted sum). All criteria presented within the last column form the criteria set which will be used for comparisons presented further in the paper.

Table 1. Labels, names, and descriptions of criteria.

Criterion Label	Criterion Name	Description of Criterion and Its Assessment Technique
C1	Data collecting	Criterion assesses how data are collected from other providers. Possible assessment is determined as follows: Public domain, on official request, or on the market.
C2	Data attainability	Criterion evaluates data attainability considering obligation when collecting data (Is data collecting defined by legal acts? By pricelist? With the contract or without fee?).
C3	Data availability	Criterion assesses the availability of needed data by rating the available public data or the procurement procedures that are required to get needed data. According to procurement procedures, availability of data is further assessed as follows: clear procedures, problematic procedures, or absence of procurement procedures.
C4	Time period	Criterion assesses the time period for getting required data from another provider(s). Assessment is provided as follows: in a week, one to two weeks, two weeks to a month, and more than a month.
C5	Data update	Criterion assesses the frequency of updating data as follows: less than five years, at least every five years, once a year, and several times per a year.
C6	Requirements for data	Criterion assesses the user requirements for data of each data theme by determining what data themes are wanted by users. It is assessed by counting the number of users that require an assessed data theme.
C7	Provided data	Criterion assesses the provision of each data theme to users by determining what data themes are provided to the users. It is assessed by counting the number of data themes that providers already offer at no charge to the users.

Criterion 2 assesses how data are collected from other providers. Assessment according to this criterion is provided as a weighted sum of a number of assessed data themes that are collected according to following categories of providers: weight for collection from the public domain is 10, weight for collection on an official request is 5, and weight for collection on the market is 1.

3.1.3. Identification of Relevant Data and Data Classification

A unique questionnaire was developed to achieve the identification of relevant data in accordance with the defined goals. This research was conducted at the end of October/beginning of November 2014. The questionnaire contains 25 questions grouped into five themes: General questions, organisational affiliation, spatial data cognition, and about data and data distribution. The spatial data cognition group of questions refers to the level of user awareness of SDI, MSDI, and the INSPIRE directive, as well as the concept of the usage of geoportals. The group of questions related to data refers to issues that are related to the availability of the existing spatial data by themes provided by experts, organizations, and data that they like to use. It also refers to data updates and how data is provided to other users. The data distribution group of questions refers to questions about the acquisition of spatial data from other stakeholders.

Given the specific combination of semi-structured interviews and questionnaires, the response rate was 100%.The total number of respondents was 72. Respondents are identified in the previous section as groups of stakeholders. They are spatial data experts from organisations involved in MSDI development in the roles of providers and users of spatial data and have different roles in data distribution. Therefore, respondents are ranked by their proportion of handling data within the MSDI.

One-third of the respondents represented organisations that are spatial data users only. Most are both spatial data users and providers (62.5%), and 5.6% are only providers from the State Geodetic Administration (responsible for land data, while the maritime part is the HIRC's responsibility) (Figure 3). As a core question in this research refers to data (in addition to gaining useful information about user habits), we tried to establish a data framework that consists of identifying datasets, dataset classification into data themes, and distribution procedures. Experts who work with the spatial data identified data that has already been provided by their organisation also expressed their need for certain datasets.

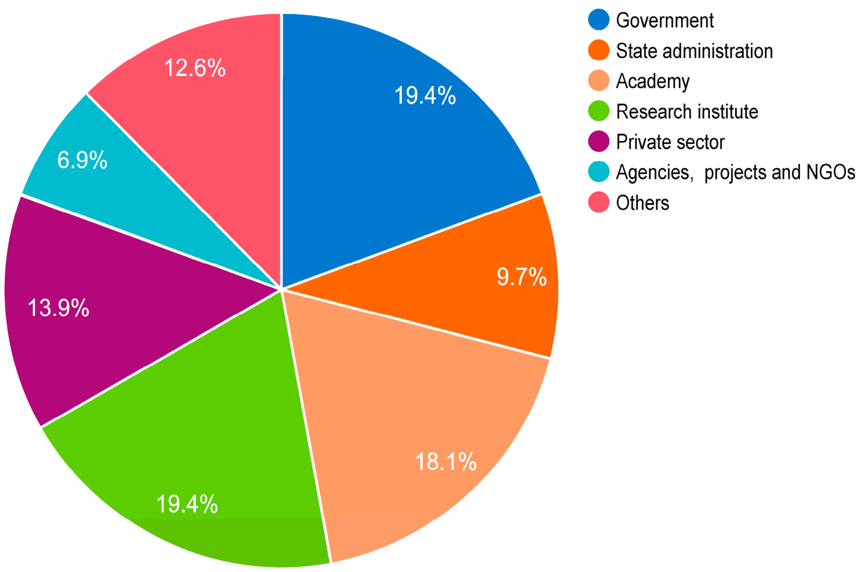

Figure 3. Questionnaire respondents.

At the questionnaire design and testing phase, we identified and classified datasets into the following eight themes according to their similarity:

- Topography (orientation facilities, ports and harbour facilities, ports infrastructure);
- Hydrography (topography of submarine, geology, coastline, rocks and reefs, sea areas and boundaries, utility infrastructure, meteorology);
- Oceanography (tides, ocean currents, nutrients and oxygen, sea temperature, salinity and density);
- Maritime affairs (maritime routes, navigational aids—lighthouses, buoys, fog signals and day beacons, navigation services);
- Biology (phytoplankton and zooplankton, marine ecosystems, marine species and populations, seabirds, toxic elements);
- Ecology (nature protection, pollution);
- Industry (fisheries, oil and gas platforms exploitation);
- Tourism (facilities and services for small boats, tourist information, diving areas, archaeological sites, nature parks and protected reserves, beaches and recreation areas).

Respondents used the "other" possibility in the questionnaire to also bring up water construction and water buildings (topography), estuaries, coastline shape (hydrography), monitoring data (oceanography), sea habitats, monitoring data (biology), and weather forecasts for sailors (maritime affairs).

3.2. The Second Phase: Priority Ranking of Data Themes

The second phase consists of two parallel actions followed by a comparison of data themes and their priority ranking. The first action of the second phase deals with the assessment of data according to results of the questionnaire analysis.

3.2.1. Assessment of Data Themes

Data themes were assessed according to defined criteria and are based on the analysis of information obtained through stakeholder interviews using a structured questionnaire. Almost four-fifths (79.7%) of respondents described problems with the procurement or lack of clear procedures for spatial data procurement, indicating poor availability of spatial data.

Spatial data is provided to 79.2% of surveyed users within one month, while 16.7% receive data within one week. The time lag for acquiring required data is considered unsatisfactory. A complete assessment of the data themes according to all defined criteria is presented in the Supplemental Materials, Table S1. Table S1 presents the assessment of eight data themes according to seven defined criteria. Assessment is carried out in accordance with the corresponding techniques for each of the criteria as described in Table 1. It is obvious that assessment according to different criteria is provided by different assessment techniques and in different measuring scales depending on the logic of each criterion.

Table 2 also presents the approach to forming the preference according to each criterion. For three criteria it is established that they had to be minimized; that is, lower values of alternative assessment by these criteria are preferred. For the remaining four criteria, it is established that they had to be maximized, which means that higher values of alternative assessment by these criteria are preferred. Each criterion has its own preference function, and these functions represent how the preference of decision-maker (between two assessed themes) is formed by that single criterion. The value of the preference function is between 0 and 1. The smaller the value of the function is, the larger the indifference of the decision-maker. If the value is closer to 1, the preference of the decision-maker is higher. In the case of strict preference, the value of the function will be 1. How many types of preference functions there will be depends on the characteristics of the determined and used criteria [28]. In this case, all criteria have a V-shaped preference function. The V-shape is a linear function that accounts for moderate comparison of the themes providing linear correlation between indifference (0) and strict preference (1). Preference functions are actually selected based on the practical nature of the criteria. Additionally, it must be emphasized that PROMETHEE does not restrict the decision-maker to only those six types, and one can have the freedom to define its own preference function if none of proposed six types [31] suits her/him.

Table S1 shows that oceanography is the best ranked and biology is the worst ranked theme, according to C1 and C2. According to C3, the best ranked is hydrography and the worst ranked is biology. The best ranked according to C4 is hydrography, and the worst is industry. Oceanography is the best ranked and tourism is the worst ranked according to C5. Assessment by C6 defines topography as the best ranked theme and biology as the worst theme. According to C7 best ranked is hydrography and worst ranked is industry. Furthermore, after Table S1 it can be concluded that ecology and maritime affairs are always somewhere in the middle.

This provided insight into rankings of themes according to the assessment by each criterion individually (suggesting the absence of one theme that prevails), but also makes evident the need for the multicriteria approach and the usage of appropriate multi-criteria methods since not one theme prevails above all others.

In all multicriteria problems, aside from the several different types of criteria, it is also evident that there are different levels of importance of each criterion within a criteria set. When using multi-criteria methods, the level of importance of each criterion is expressed by its weight. Determination of criteria weight is a very important step because through them opinions of all stakeholders are introduced in comparison to data themes.

3.2.2. Determination of Criteria Weights (AHP Method)

Parallel action to the assessment of data themes refers to the determination of criteria weights by the AHP method, whose selection for such a purpose within PSC was justified previously (Section 2). Using the AHP method, the preliminary importance of each criterion in a defined criteria set is based on each stakeholder group's opinion. Seven sets of preliminary criteria weights are defined. The final value of each criterion weight ("compromised weight") within the final criteria weights set ("compromised criteria weights set") is gained as an average mean value of seven preliminary weights for that criterion from all seven preliminary criteria weights sets. Table 2 shows values of seven preliminary criteria weight sets within rows 4–11. Compromised criteria weight sets with increased weight values for each criterion are shown in the last row of Table 2.

Table 2. Final values of criteria weights.

		C1	C2	C3	C4	C5	C6	C7
Criteria	**Criterion Label**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
	Min/Max	**Max**	**Min**	**Max**	**Min**	**Min**	**Max**	**Max**
	Preference Function	**V-shape**	**V-shape**	**V-shape**	**V-shape**	**V-shape**	**V-shape**	**V-shape**
Stakeholders	*Government*	0.09	0.06	0.09	0.06	0.35	0.175	0.175
	State administration	0.1	0.12	0.12	0.08	0.3	0.15	0.15
	Academy	0.1	0.15	0.15	0.1	0.15	0.25	0.1
	Institutes	0.1	0.1	0.1	0.1	0.18	0.3	0.12
	Private sector	0.09	0.24	0.09	0.18	0.12	0.08	0.2
	Agencies, Projects, and NGOs	0.18	0.24	0.12	0.06	0.08	0.28	0.04
	Others	0.21	0.3	0.06	0.03	0.08	0.24	0.08
Compromised weights		0.13	0.17	0.1	0.09	0.18	0.21	0.12

The compromising weight of each criterion is stated as a percentage share of the total weight of all criteria (which is 100%). Adopted weights are shown in Figure 2 as dashed rectangles within the last hierarchical level by which criteria are presented.

3.2.3. Priority Ranking of Data Themes by the PROMETHEE Method

The results of both parallel actions are inputs for comparison and priority ranking by the PROMETHEE method. Using Visual PROMETHEE [32], all assessments were processed by the multi-criteria method, PROMETHEE II. This method is used to establish a priority ranking (for inclusion in the development plan) of the seven analysed data themes. PROMETHEE methods provide priority ranking by mutual comparison of all data themes by all criteria with respect to the opinions of all stakeholders. Opinions of stakeholders are expressed through determined weights as described in the previous subsection. The results of the application of the PROMETHEE II method (which gives a complete ranking) are displayed in Figure 4.

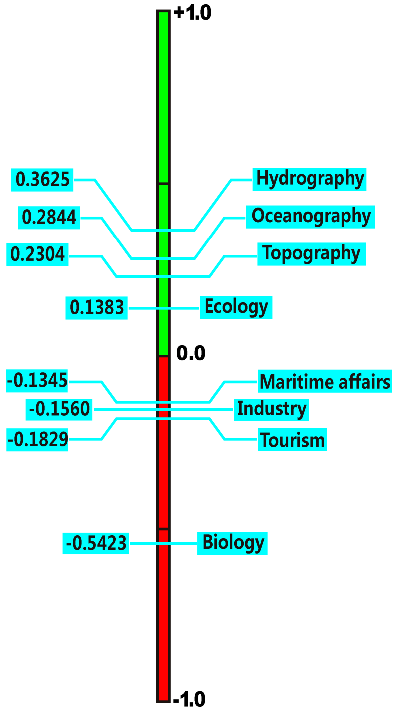

Figure 4. Priority ranking of data themes.

Net preference flow shows preferences among different data groups by the decision-makers. The amount of net preferences of flow provides an even finer ranking between positive and negative preferred groups of data, showing how long a certain group of data is better or worse than others.

Value data themes are ranked according to the net preference flow Φ. The best ranked is the data theme hydrography, with the highest Φ (+0.3625), whereas the data theme biology had the lowest Φ value (-0.5423), which is the worst ranked. As shown in Figure 4, the data themes comprise three groups. The first group consists of four data themes (hydrography, oceanography, topography, and ecology), the second consists of three data themes (maritime affairs, industry, and tourism) and the data class named biology stands as the third group. The ranking list of data themes shown in Figure 4 is the input for the third phase.

The grouping of data into three groups clearly indicates the personal preferences of the decision-maker for the group of data contained in each of these three groups. It can be concluded from the above that it is necessary to set up activities in the plan for the establishment of MSDI in a way that will take the above grouping into account.

3.3. The Third Phase: Definition of the MSDI Development Plan

The third phase results in a definition of the MSDI development plan according to the rankings determined in the preceding phase, three identified groups of data themes, and available resources (funds).

The provided MSDI development plan must be perceived as follows: In its first development phase, four top-ranked data themes (hydrography, oceanography, topography, and ecology) are included. The second development phase consists of data themes ranked from fifth to seventh place (maritime affairs, industry, and tourism), and during the last development phase, biology data must be introduced. The first group will be included in MSDI, and responsible authorities need to ensure sufficient resources within the first investment cycle. If it is not possible to ensure fully-required funds, then data themes from the first group must be included in the order of their rankings. The second group stands as the basis for the shaping of the funds' projection required for the realisation of the second development phase, while the third group can be used for a rough determination of the minimal number of phases/investment cycles required for MSDI completion (duration assessment). It is important to perceive second and third phases only as projections, but not as real phases, because the MSDI must be formed very flexibly and adaptable to current needs. Each next phase of the MSDI development plan must be defined before the end of the previous one in order to ensure the continuity of MSDI development, as well as data actuality. This approach also ensures the actuality of the MSDI development plan as a whole. The next phase must be provided by the usage of the proposed PSC, but without analysing/prioritising data themes that are already included in the MSDI. The procedure is repeated until all themes are included.

4. Discussion

The emphasis here is on the issue of quality results that enable progress past the first phase of MSDI development. In particular, there are significant changes to users' data needs. Thus, the partly-established MSDI is incompletely adapted to real needs and correction of dataset themes should be carried out, including those to be included in later phases of the project. This becomes particularly significant in the case of some other thematic SDIs in which it is possible to identify many more data themes. If the minor changes in user needs for data can significantly influence their priority rankings, then the intervals of stability of the provided solution in the form of ranking are extremely narrow. A follow-up survey of stakeholders can evaluate the effectiveness of the proposed MSDI development to measure the uptake of the MSDI and improve the assessment measures, such as time for data distribution.

Nothing within the proposed PSC keeps MSDI planners from allowing data producers from preparing their own contributions to MSDI in parallel. Actually, the presented PSC enhances this approach, simultaneously considering the specificities of the MSDI development process, such as detected constraints (primarily) regarding capacities and funds. These constraints have to be incorporated into MSDI development planning because different data sources and producers have different constraints (i.e., different human resource capacities and/or different available funds to produce data), resulting in different abilities to produce adequate data in terms of quantity or, perhaps, actuality. Therefore, PSC is proposed to be used when MSDI development must be established step-by-step (i.e., when all data cannot be included in it at once). The above stated is emphasized even more in developing countries characterised by a lack of both capacities and funds for instant development of whole MSDI.

The proposed concept proved feasible in all its steps in a real example. More specifically, it can be said that it allows adequate involvement the operation (for end-users) portion of stakeholders within each phase, and the results of each stage (if it is expected quality) are used in the next phase. For example, its flexibility in terms of the involvement of many different stakeholders in a way that allows the achievement of better results, in terms of avoiding confusion and conflict between them. In this way, stakeholders participate in the planning of system development and reducing the level of conflict. If is it possible to expand/redesign the proposed PSC to enable the introduction of such additional analysis (to achieve better data grouping and identification of the development phases), the numerous conflict points emerging from the different needs of stakeholders to a future SDI during its development can be avoided.

5. Conclusions

The presented PSC proved to be applicable and useful for MSDI development planning because it is successfully validated in Croatia. Using PSC the draft development plan is formed and what is even more important it includes opinions of all relevant stakeholders in Croatia. One of outcomes of PSC validation was identification of all relevant MSDI stakeholders (interested parties).

Their identification and preparation proved to be a good start for the analysis of the actual situation and user needs. Also it serves as a preparation for the next phase. By including the stands/opinions of all stakeholders in defining criteria and their weights which are further used for the priority ranking (by multicriteria decision making method PROMETHEE) as compromised weights the equally appreciation of all stakeholders is introduced in planning process.

Analysing the results of the priority ranking (draft MSDI development plan) defines the project activities to be implemented during the MSDI development in Croatia. More importantly, priority ranking defines the order of acitivites within implematation process maximizing the impact of each activity on stakeholders requiremets even before MSDI is fully developed.

The proposed PSC contributes to the MSDI development process because inclusion of the stakeholders accomplished:

- their better acquaintance with the problems of MSDI in Croatia as well in general and of its development,
- mutual agreement on evaluation techniques within priority ranking prosess,
- decision-making consistency of higher level during planning.

The result is the creation of better overall conditions for the MSDI development, especially of those in Croatia. All stakeholders now know what to expect during the process of MSDI development, particularly regarding the order of the data themes implementation.

Specific conclusions achieved within the research presented in this paper are listed below.

The proposed development plan consists of three steps (suggesting simple implementation). In our opinion, these steps must correspond to the three investments or budget periods defined by the HIRC—the organisation responsible for developing and implementing Croatian MSDI. Through the first step, data themes identified by the top-ranked group should be included in the new Croatian MSDI. That way, spatial data related to hydrography, oceanography, topography, and ecology—which are recognised as the most required and useful for all users—will be the first available to them. Inclusion of those data themes into MSDI at the beginning of its development will provide the greatest positive impact on the society of spatial data users. The second step must provide inclusion of the second group of data themes, comprising spatial data related to maritime affairs, industry, and tourism. Finally, in the third step, Croatian MSDI will be fully fit for users by the introduction of biological data.

The indirect contribution to the introduction of this approach in the planning of the project to establish thematic SDI should be viewed in the context of its use for planning to establish more thematic SDIs. Improving the proposed PSC in future research should be directed to study the relationship with the highly dynamic nature of the environment on which it is applied. The median consists of direct and indirect users of data information within a future MSDI. A characteristic of users is the relatively frequent change in their needs, which mainly depends on the needs of the markets they serve, their products, and their services.

Supplementary Materials: The following are available online at www.mdpi.com/2220-9964/6/4/117/s1. Table S1: Assessment of data themes according to criteria set.

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