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Designing Development Readiness Indicators and Roadmap for Petaflops Scale Supercomputers

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ABSTRACT

Recently, supercomputers and high-performance computing (HPC) have caused significant progress in many fields, including industrial and research fields of artificial intelligence, data science, big data, Internet of Things, as well as large scale web applications. Regarding this characteristic, the supercomputer field becomes one of the strategic issues in developed and developing countries. Successful HPC development requires a robust infrastructure that effectively depends on a multidimensional policy and roadmap, covering all aspects of HPC services. In this regard, a comprehensive roadmap is necessary to design and achieve high-performance computing services. This paper proposes a comprehensive roadmap focusing on several strategic areas, including research activities, infrastructure and platforms, data processing, standard regulations, applied services, and business development. The roadmap follows an evolutionary strategy where strategic regions evolve in parallel. Also, in this paper, the Supercomputing Development Readiness Indicators (SDRI) inspired by the "Network Readiness Indicators" (NRI) are presented and the proposed roadmap uses them. The proposed roadmap is then compared with two other hypothetical roadmaps with the timing and priority of different strategic areas in terms of progress and completion time. Evaluation of the proposed roadmap based on the SDRI specification shows the effectiveness of the proposed method in creating and developing the services of a petaflops scale supercomputer.

Keywords: HPC Services, Roadmap, Strategic domain, Coevolutionary.

1. Introduction

The expansion and development of information technology in the last two decades have created a huge amount of data processing needs. Along with this development, ultra-fast processing services can process and compute data sets with sizes beyond the capability of common software tools in a short period of time.

Contemporary usage of HPC[1] is in various fields, including bioscience, geographical data, oil and gas industry, electronic design automation, climate modeling, media, and entertainment.

Regarding definition, supercomputer refers to the most powerful computers available at any time. Therefore, the definition of supercomputer can have a floating concept because with the advancement of technology, it can provide different definitions in time and place. As a common definition, a supercomputer is a number of servers with high processing capability, all of which are used in a cluster with high-speed connections, several levels of storage and a set of application libraries to run a high-performance computing application[2] [1].

Supercomputers are fast and precise overall, to solve larger problems, is well-suited to kinds of algorithms that are intrinsically parallel in essence. Examples of the world's most powerful supercomputers are Summit [2] developed by IBM and Titan [3] in America, Fugaku [4] supercomputer in Japan, and Tianhe-I [5] supercomputer in China [6].

Currently, According to the needs assessment and identification of the current situation of the country that has been done for the national information network, the development and needs of the country in the field of supercomputers are very serious. Also, considering the general policies of development in the country, the realization of the creation of petaflops scale supercomputer is in line with the laws and policies of the upstream, which are a series of upstream documents that explain the necessity of doing such works, including:

- Creating a suitable platform for communication and information gathering and processing
- Expansion of local treatment capacity and services

As a result, high performance processing in applications with sensitive and big data make a potential in order to create an important driving force for innovation in services[7]. Success in implementing HPC projects depends on a clear roadmap covering different aspects such as data processing methods, legal issues, business processes, and technical, cultural, and social influences [8]. Moreover, we need a clear strategy for leveraging HPC services economy in any country [9].

The suggested roadmap is provided as a driving engine to integrate activities in basic research and application, as well as to determine the driving policies for development of this area. Moreover, the proposed roadmap, while giving a comprehensive picture of HPC Services in an enterprise

[1] High Performance Computing
[2] https://www.intel.com/content/www/us/en/high-performance-computing/what-is-hpc.html

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application and presents a desirable situation in this area. This roadmap has a co-evolutionary method that its players and stakeholders evolve in a parallel model. The main contributions of this paper are:

1. Providing a new development roadmap for creating a supercomputer that contains an integrated and evolutionary view of the fields of supercomputers. This roadmap consists of the following innovations:

- Proposing a new supercomputer life cycle for the roadmap
- Proposing a new supercomputing business canvas model for the roadmap
- Proposing a new supercomputer service development model for the roadmap
- Considering all the strategic area related to supercomputer for the road map and prioritizing and considering weight for them according to the current situation

2. Proposing a new readiness indicators for the development of supercomputers inspired by NRI[3] .
3. Proposing a new method of evaluating different areas of supercomputers.

1.1. Supercomputer Applications in surveillance and security systems

Computers are powerful arms and scientific progress in all fields, including surveillance and security systems such as police and law enforcement. With the advancement of technology, the speed and accuracy of supercomputer processing has increased and more powerful supercomputers are introduced every year. Some of the most important applications of supercomputers and ultra-fast processing in surveillance and security systems such as police and law enforcement are the following:

1. Using a supercomputer to optimize the network and police information infrastructure by implementing artificial intelligence on the supercomputer platform to predict the traffic load and required resources in the form of cloud computing infrastructure.
2. The use of supercomputers to reduce the time of implementing information technology applications in systems such as video line monitoring and future forecasting systems or storing security data of the police command.
3. The use of supercomputers in the security of software and hardware communications of police command to implement various augmented and virtual reality and hold dangerous trainings in the field of surveillance and security online such as war plane navigation.
4. The use of supercomputers in monitoring, preventing and detecting crimes in digital information and cyberspace. In this regard, in order to prevent damages, it is necessary to perform some simulations that require high-speed and high-precision calculations with the help of supercomputers.
5. The use of supercomputers in police intelligence, such as intelligent control and monitoring systems and data centers to provide intelligent police services, intelligent command and control of police missions, and an intelligent system for detecting and identifying traffic signs[10].

[3] Networked Readiness Index

The rest of this paper is organized as follows: Section 2 explains the data processing problems in the supercomputer roadmap. Section 3 describes the related works. Section 4 explains the proposed life cycle and business model for HPC Services. Section 5 explains the proposed development model. Section 6 explains the NRI- inspired supercomputer development readiness indicator (SDRI). Section 7 explains the evaluation results, and finally, Section 8 concludes the paper.

2. Data Processing Platforms In Supercomputer Roadmap

The supercomputing roadmap is a high-level document that charts the vision and direction of supercomputing over time. The roadmap is a strategic guidance document that provides a framework to facilitate planning and coordination for supercomputer design at all technology levels. A roadmap can be for an organization or company, across a sector or industry, at cross-industry, national or international levels [11]. A supercomputing roadmap has several ultimate goals:

- Describes the vision and strategy.
- Provides a guidance document for design and implementation.
- Aligns internal stakeholders.
- Assists in communicating with stakeholders, including customers.
- Facilitates business and design scenario planning.

In this section, the architecture of HPC hardware and software infrastructure, the process and architecture of supercomputer services, including the process of HPC services, and life cycle of supercomputer and the design steps related to the roadmap of supercomputer are briefly presented.

2.1. HPC hardware and software infrastructure architecture

Figure 1 presents the hardware and software infrastructure architecture of a supercomputer based on hybrid virtual and physical resources. According to this architecture, the supercomputer infrastructure includes five layers as follows:

Layer 1: The passive or physical part of the supercomputer.

Layer 2: Virtual and physical resource pool: which includes the sharing of physical computing resources, network, data storage and memory.

Layer 3: provisioning of compute, network and storage resources: this is done by a hypervisor. The task of the supervisor in this layer is to prepare computing, network and storage resources. The provision of these resources is done through direct hardware control or through virtualization.

Another task of the superintendent is the global management of resources so that all resources can be exploited as a processing resource.

Layer 4: Executive software in both system and functional form: this layer provides executive environments for simulation, modeling, data analysis, artificial intelligence, illustration, machine learning, etc.

Layer 5: Service delivery platforms: It includes the provision of various HPC services, including simulation, modeling, analysis and analysis of workloads, etc. These services are provided to users in such a way that users without technical knowledge can use them [12].

2.2. HPC Services Process

The processing method and dealing with HPC services are quite different from dealing with normal computing. Since HPC services have more complete specifications and attribute in nature, the normal methods are not effective solutions [5]. HPC services are handled at several stages: data collection, storing, organization, analysis, and visualization. The reference architecture serves as a foundation for developing business models and enhances the understanding of functional blocks and processing flows in the model of HPC processes. Figure 2 shows a high-level architecture based on the main block and responsibility units. As seen from the processing stage, collecting, storing, executing and presenting processes are the main tasks in the architecture. The HPC service process provides several components and sequences of processing functions that support the operation of the HPC service processing system [13].

We propose reference architecture in Figure 2, that presents the main functions and tasks in the HPC service system based on data processing according to reference [6]. In the following, we explain these steps:

1. **Processing collection**: This stage involves collection of processes from several types of Different computing sources.
2. **Processing storing and Organization**: This stage involves storing the processing into distributed systems and servers. This stage involves categorizing and arranging the processing on the basis of processes types which is different to execute.
3. **Processing computing**: After the processing has been organized (stored and arranged properly), this stage involves preprocessing calculation, processing and its execution.
4. **Processing result visualization**: When the processing run is complete, the next stage is to represent the results in useful format. In visualization the customer satisfaction is a key issue. Final step is benefit of results for further action.

Two other processes that are important in the HPC service process architecture shown in Figure 2 are:

- Security and protection of processes

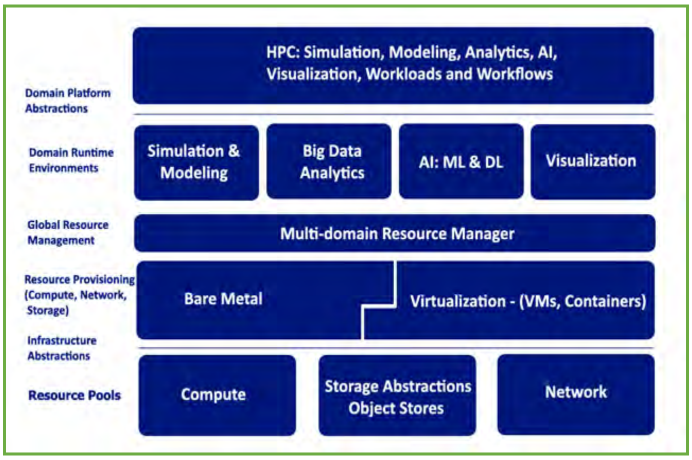

Figure. 1. Supercomputer hardware and software infrastructure [12]

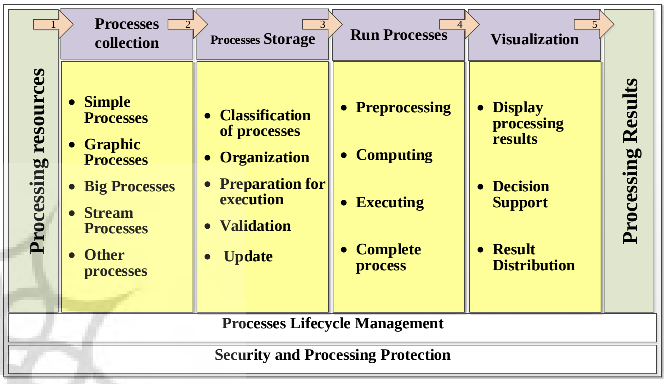

Figure. 2. Reference architecture of HPC Services Process with a functional view

- Life cycle management of HPC processes, for example, proofreading, conversion, and processing quality check, is done in this process.

3. Related Works

3.1. Related works in the field of supercomputer infrastructure design

One of the tasks related to supercomputer roadmap, project charter and supercomputer design stages includes macro and detailed design. Figure 3 shows the steps taken to design a supercomputer based on Simorgh supercomputer, with a processing capacity of 100 petaflops [2]. According to Figure 3, the stages of supercomputer infrastructure design include two parts [14]:

The first part is the needs assessment and the presentation of the supercomputer business justification plan, which includes the formulation of the project charter, business model and supercomputer construction plans. The second part is the preparation of the test plan, the detailed plan of the supercomputer, which includes the test plan and the detailed plan of different parts of the supercomputer.

3.2. Articles related to supercomputer roadmap

The paper [3] presents a roadmap for optical connections to exaflops servers and supercomputers. This technological roadmap focuses only on power connectivity and density efficiency for high-performance servers and supercomputers.

This paper reviews low cost, low power consumption, and high density optical interconnects for supercomputers and discusses their challenges. The paper [10] presents an integrated taxonomy of standard indicators for ranking and selecting supercomputers. This paper proposes an integrated feature-based taxonomy and a scoring procedure based on these indicators for ranking supercomputers, which facilitates the process of supercomputer evaluation for designers. But this article does not provide a roadmap and does not consider the strategic areas for creating a supercomputer. The paper [13] presents a co-evolutionary strategic roadmap for big data. This paper provides a comprehensive roadmap makes it possible that any business entity and organization discover a new vision for future success through collection and analysis of raw data. The roadmap has a co-evolutionary strategy that players evolve in a parallel model; but this article is only for big data development. Related articles show that now, developed countries are developing supercomputers in exa-scale dimensions [15]. Unlike the mentioned related articles and works, we proposed a comprehensive roadmap to design and build high-performance computing services. This paper proposes a roadmap focusing on all strategic areas.

4. Hpc Life Cycle And Business Model For Proposed Roadmap

4.1. HPC Life Cycle

One of the tasks related to the supercomputer roadmap is its life cycle. The layers and stages of the supercomputer life cycle are presented in Figure 4. As shown in this figure, the life cycle of a supercomputer has two main parts. The first part of the cycle consists of eight stages. In this section, the processes and activities of the supercomputer are categorized in stages for the evolution of the life cycle. The layers of the second part of the supercomputer life cycle cover all of the first part [16]. Explained as follow:

1. Supercomputer monitoring and guidance, which is the highest layer of the bio-wheel. The life cycle of the supercomputer starts from this path and the activities begin.
2. Supercomputer security
3. Management, audit and evaluation

4.2. Business Model

The traditional business model canvas is consisted of nine segments, including key players, key activities, value propositions, customer relationships, customer segments, key resources, channels, cost structure, and revenue streams [17]. The business model assists in value creation for all components, as well as benefits the key partners in achieving the objectives [18]. The proposed canvas business model for the HPC Services roadmap is shown in Figure 5. The key components of the business model canvas in Figure 5 are described as follows. The key players in the canvas business model are distribution partner, university and research center, private and public companies, telecom service provider, medical centers, cloud service provider, IOT service provider and smart drivers.

1- Requirements assessment and justification and business plan
• Compilation of the project charter
• Feasibility assessment and preparation of explanatory plan
• Development of a stakeholder cooperation model
• Investigating and determining the location of HPC center
• Review of emerging technologies and standards
• The first stage of bidding and selection of the short list of participants
• Macro design: physical infrastructure of platform, Hardware and software infrastructure and Service design based on business model
2- Preparation of test plan, detailed plan and call documents
• Preparation of system test plan, infrastructure and HPC services
• Detailed design of passive and active infrastructure
• Detailed design of the software parts
• Preparation of documents including RFP, LOM and technical, legal and business annexes and qualitative, technical and financial indicators

Figure. 3. Proposed steps for designing a supercomputer in Petaflop

Layer 1: Monitoring and Control		
1- Location, analysis and design stage • Location and supercomputer design • Compilation of the test plan • Detailed supercomputer design • Preparation RFP, LOM of supercomputer	**Layer 2: Security**	**Layer 3: Management, audit**
2- The stage of procurement and supply of resources		
3- Construction stage		
4- Test and delivery stage		
5- Operation phase and business continuity		
6- Technical support, maintenance stage		
7- Optimization and modernization stage		
8- Immigration and retirement stage		

Figure. 4. Reference architecture of HPC Life Cycle with a functional view

The key activities in the model are data collection and storing, data computing, computing services, and customer service management. Value propositions include fast processing for artificial intelligence services, parallel data computation for big data analytics, weather forecast, medical services, traffic control, and business unification. The volume and speed of processing are key parameters and advantages of supercomputers in the given ecosystem. Customer relationships include automation and manual, user classification, access classification, access priority levels, special access and pay-as-use plans. Customer segments include internet users, data provider, economic planner, professional users, private and public users, entrepreneurs, mobile users and drivers. Key resources are data centers, internet services, mobile applications, business operations, healthcare services and data analysis [1].

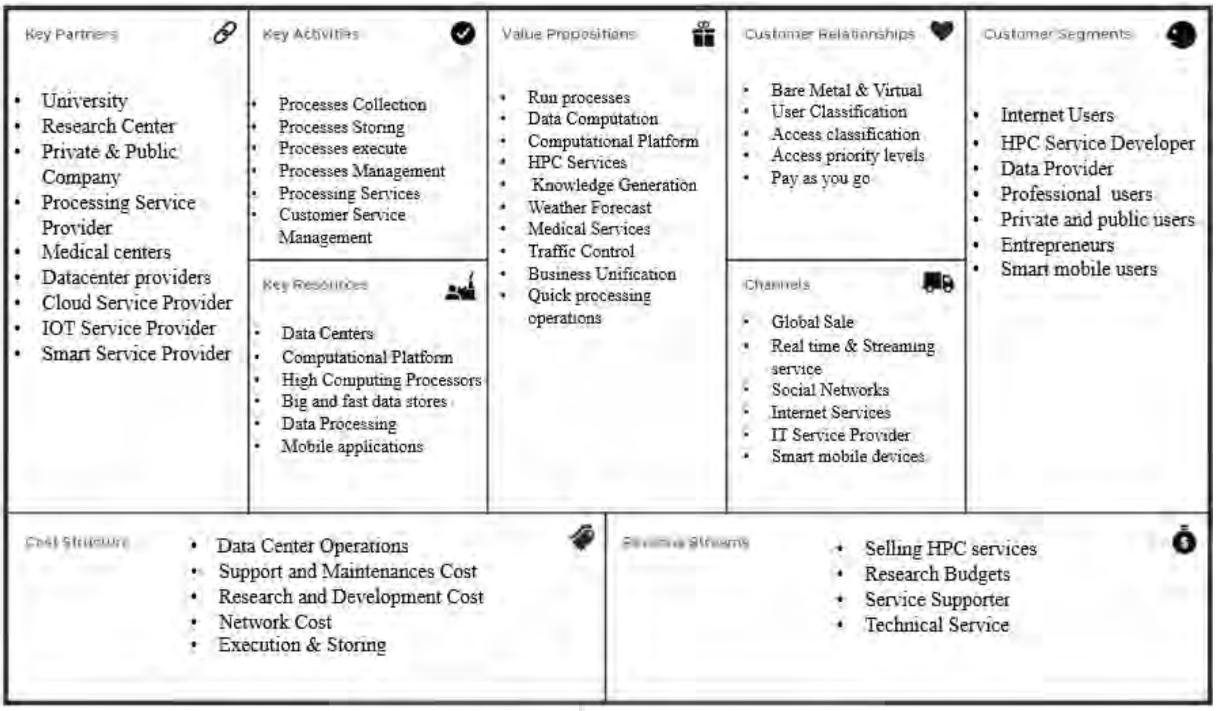

Figure. 5. Proposed business model for the HPC Services roadmap

Channels include global sale, real time and streaming service, social networks, internet services, call centers and mobile devices. Cost structure includes operations costs, support and maintenances cost, research and development cost, channels cost, and collection and storing costs. Revenue streams include enterprise analyze sales, research budgets, product offers; technical services and internet usage packages [19].

5. Hpc Development Model for Proposed Roadmap

Both developed and developing nations are planning to develop HPC services technology. Thus, with the rapid development of information technology in modern countries, any delay in the design and setting up of HPC Services can result in major losses in national economies [20]. In this direction, countries should acquire the benefits of new HPC services by implementing a well-developed strategic roadmap. This section presents our proposed roadmap for developing HPC services technology. We have utilized the logical procedure depicted in Figure 6 to extract our proposed roadmap.

As shown in Figure 6, the logical method steps for the HPC processing service development roadmap are:

1. First, we concentrate on the current state of an entity, such as a country, and the visions it wants to reach.
2. Second, we forecast the technical, economic and social requirements.
3. Third, based on forecasted requirements, we shape the favorable condition in different domains.
4. Fourth, we extract the strategies of HPC Services development considering the current challenges in this direction.

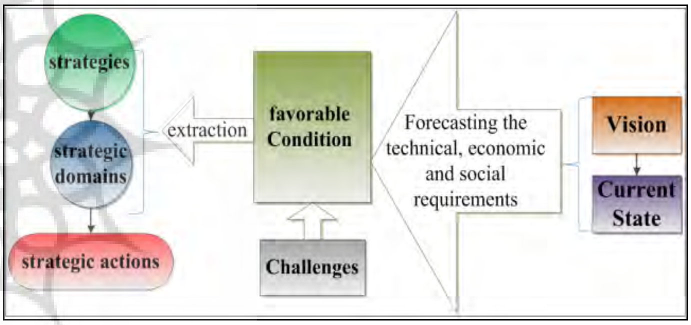

Figure. 6. Logical procedure for HPC procrssing services development roadmap

5. Fifth, we define the strategic actions to reach the strategic goals in different strategic areas.

Our proposed roadmap is composed of five main components including strategic vision, strategic domains, strategic goals, strategic actions, and the stakeholders and players in each strategic domain.

5.1. Strategic vision

The strategic vision for HPC Services development refers to HPC Services as a driving force for development of technologies of the society in terms of storage, processing and generating new solutions to improve and promote human life.

5.2. Strategic domains

As shown in Figure 7, our proposed roadmap consists of six strategic domains, including (1) research, (2) infrastructure and platform, (3) technologies and data processing, (4) standard and regulation, (5) service and application and eventually (6) business.

5.3. Strategic Goals

The proposed roadmap consists of a specific strategic goal in each strategic domain. The strategic goal in the research domain is "supporting the elites and increasing motivation to maintain local experts". The strategic goal in the infrastructure and platform domain is "relying on the local capabilities, resources and technologies for infrastructure development", and "developing powerful and secure infrastructure platforms". The strategic goal in the technologies and data processing domain is "development of local technologies and tools in accordance with the resistance economic policies" [21]. The strategic goal in the standard and regulation domain are "passing the required Laws and regulations ", and "extracting the local standards". The strategic goals in the service and application domain are "integration of services" and "development of services along with savings and resource optimizations". The strategic goals in the business development domain are "concentrating on HPC Services" and "supporting the local HPC Services ".

5.4. Strategic Actions

We propose several strategic actions to be taken to realize each of strategic goals defined for each strategic domain. The proposed strategic actions in the research domain are:

- Creating specialized workgroups.
- Creating an effective link among industry, academia, and end users.
- Increasing interaction between research and development sections and knowledge based corporations.
- Determining research priorities and provide funds and supporters.
- Determining educational plans and policies to develop the required skills.
- Equipping laboratories and providing required hardware platforms.

The proposed strategic actions in the infrastructure and platform domain are:

- Installing and commissioning the software platforms and cloud solutions.
- Developing and commissioning the distributed NoSQL storage platforms.
- Developing the high performance interconnection networks based on optical high bandwidth technologies.
- Developing the fast switching and routing equipment.

The proposed strategic actions in technologies and data processing domain are:

- Development and localization of the required technologies for storage and process
- Development and localization of parallel processing tools
- Creating and development of applications for different sections

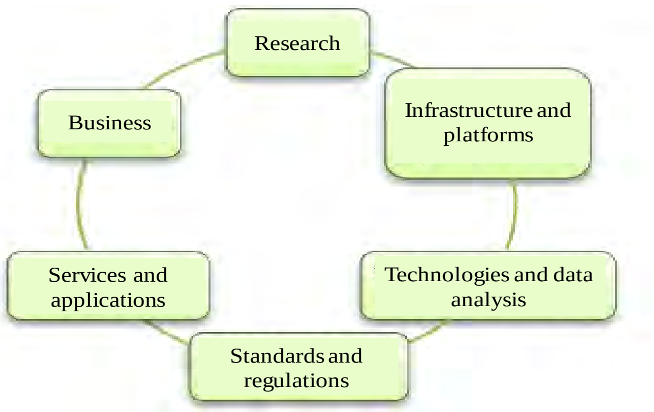

Figure. 7. Strategic domains for HPC procrssing services roadmap

- Supporting startups and new research
- Training and educating specialized workers

The proposed strategic actions in standard and regulation domain are:

- Standardization in design and construction of supercomputers
- Specifying the regulations and laws related to construction and commissioning of supercomputers
- Defining the process, law, and regulations for supercomputers, storage, and process
- Defining the required laws for data intellectual property and business processes
- Defining the HPC service tariffs.

The proposed strategic actions in service and application domain are:

- Generating and developing new processing services and service tools
- Generating governmental and private service platforms
- Supporting the local tools and products

The proposed strategic actions in business development domain are:

- Creating and developing effective business models for HPC Services
- Creating the required tools for measuring and evaluating processing services value
- Generation and Export of HPC Services technologies to neighbor countries
- Developing solutions for interaction and increasing competition between active entities

5.5. Stakehoders and players

Some of the HPC Services players are active and make cooperation in each strategic domain, as shown in Table 1. The roadmap has a co-evolutionary method that players evolve in parallel.

5.6. Proposed Roadmap phases

In this section, we propose the roadmap for HPC Services development in three separate phases, as shown in Figure 8, including:

Phase 1: Study and research

a) Research

Phase 2: Design and implementation

a) Infrastructure and platform development

b) Technologies and data analysis development

c) Standard and regulation development

Phase 3: Exploitation and development

d) Service and application development

e) Business development

6. Nri-Inspired Supercomputer Development Readiness Indicators (Sdri)

In this section, the NRI dataset was inspired and the Supercomputer Development Readiness Index (SDRI) was extracted. Then SDRI indicators have been used to evaluate the proposed roadmap [9]. NRI evaluates the effect of information technology on a global level and shows the readiness of countries to use information technology in their economy. The NRI provides a useful conceptual framework for decision makers and consists of four sub-indices. The first three sub-indicators of NRI are considered drivers for the fourth sub-indicator, i.e., the effects of information technology. These four sub-indices are divided into ten pillars and provide about 50 separate indicators in total. The score of these four sub-indices is the average score of these elements, and the score of the network readiness index is the average score of these four sub-indices. For each category *i* composed of *K* indicators, the indicators' values are computed using Equ. (1).

$$Category_i = \frac{\sum_{k=1}^{K} indicator_k}{K} \quad (1)$$

Table 2 shows the details of NRI indicators and their corresponding values in parentheses in the range of 1 to 7 for Iran in 2015 for all indicators and sub-indices. We have mapped our strategic areas inspired by NRI on SDRI indicators. Table 3 shows the strategic areas of the roadmap and their corresponding NRI values for 2015 in Iran. In this table, strategic areas include research, infrastructure, technologies, regulations, services, and business. Also, in this table, indicators include skills, digital infrastructure and content, business and innovation environment, political and regulatory environment, individual use, government use, business and innovation environment, affordability, commercial use, economic effects, and social impacts.

The value values in Table 3 are considered as the state of the country in 2015. We use these values to start supercomputer development for the following years. According to these numbers and stages of the strategic areas considered in the roadmap, we determine in which year we can reach the goal of having a 100 petaflops supercomputer in the country.

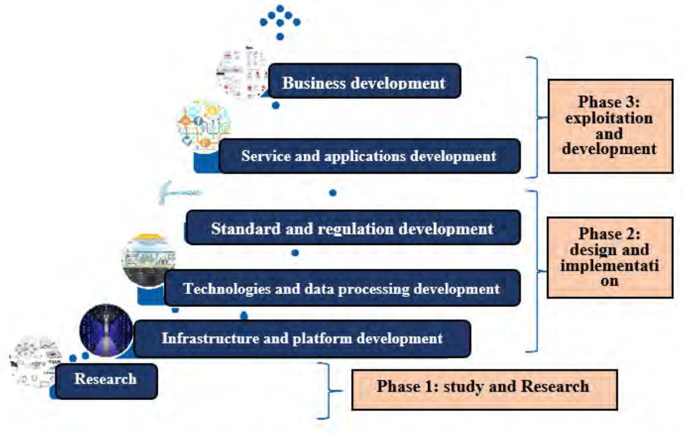

Figure. 8. Steps of the roadmap for designing and building HPC services

Table 1. Stakeholders And Players

Stakeholders and players	*Research*	*infrastructure and platform*	*technologies and data analysis*	*Standard and regulation*	*Service and application*	*Business*
HPC provider	✓			✓	✓	✓
HPC consumer				✓	✓	✓
System orchestrator	✓	✓	✓	✓	✓	✓
Application provider	✓		✓	✓	✓	✓
Framework provider	✓	✓	✓	✓	✓	✓

The weights of each strategic area are described in Table 4.

The rate of progress in each strategic area in each year according to the rate of initial progress in SDRI is calculated by Equ.(2).

$$D_t = D_{t_0} \times (1-w)^{t-t_0} \quad (2)$$

In this formula, D_{t0} is the progress index of a strategic area in the starting year of t_0. Also, D_t is the rate of progress in year t and w is the weight of the strategic area in the road map. For the proposed roadmap, we have used Equ.(3) to find the best weight for each strategic area. According to this formula, the weights in the proposed road map are considered according to the progress in each strategic area, so that the more the progress in one strategic area is greater than the others, the less weight is considered.

$$G = Argmin\ (F(SDRI0, w1, w2, w3, w4, w5, w6))$$

$$\sum_{i=1}^{6} w_i = 1 \quad (3)$$

In this formula, *F* is the progress rate function of the whole project according to the initial values in SDRI Indicators of the roadmap plan, and G will be the result vector of weights. Also, w_i is the weight of each of the six strategic areas, normalized to 1, so the summation is one.

Table 2. Indicators Details of Nri, Sdri and Values

Indicator	Details NRI	Details NRI	value
Political and regulatory environment (3.4)	Effectiveness of law-making bodies*	Effectiveness of law-making bodies in HPC	3.6
	Laws relating to ICTs*	Laws relating to HPCs	3.3
	Efficiency of legal system in challenging regulations	Efficiency of legal system in challenging regulations in HPC	3.4
	Software piracy rate, % software installed	Software piracy rate, % software installed in HPC	(n/a)
Business and innovation environment (4.1)	Availability of latest technologies	Availability of latest technologies in HPC	3.9
	Venture capital availability	Venture capital availability for HPC researchs	1.9
	Total tax rate, % profits	The amount of income from providing services and current expenses	44.1
	No. days to start a business	No. days to start a business fot HPC	12
	No. procedures to start a business	No. procedures to start a business for HPC	6
	Intensity of local competition	The number of case projects in the field of supercomputers	4.4
	Tertiary education gross enrollment rate, %	Tertiary education gross enrollment rate in HPC, %	55.2
	Gov't procurement of advanced tech	The amount of income from advanced technology services	3.2
Infrastructure (3)	Electricity production, kWh/capita	The amount of electricity and energy in supercomputer data centers	3178.1
	Mobile network coverage, % population	The amount of demand for supercomputer computing services	96
	International Internet bandwidth, kb/s per user	The amount of supercomputer storage capacity	4.6
	Secure Internet servers per million population	Number of supercomputer applications	1.3
Affordability (5.8)	Prepaid mobile cellular tariffs, PPP $/min	Supercomputer service tariffs	0.12
	Internet and telephony sectors competition index, 0–2 (best)	Income from supercomputer services	0.86
Skills (4.7)	Quality of educational system	Quality of educational system for HPC	3
	Secondary education gross enrollment rate, %	Student education enrollment rate, %	86.3
	Adult literacy rate, %	Adult literacy rate in the supercomputer field for HPC, %	86.8
Individual usage (2.9)	Mobile phone subscriptions/100 pop	The number of users and customers of supercomputer services	84.2
	Individuals using Internet, %	Utilization rate and efficiency of supercomputer use	31.4
	Households w/ Internet access, %	Percentage of people with access to a supercomputer	35.8
	Use of virtual social networks	Sum of used supercomputer processing (processing cores used in projects)	3.7
Business usage (3)	Firm-level technology absorption	Firm-level technology absorption for HPC	3.7
	Capacity for innovation	Number of SCI and ISI articles in the field of supercomputers	3.5
	PCT patents, applications/million pop	PCT patents, applications/million pop for HPC	0.1
	Business-to-business Internet use	Business-to-business Internet use for HPC	3.6
	Business-to-consumer Internet use	The number of copyrighted software in the field of supercomputers	3.6
Government usage (3.4)	Importance of ICTs to government vision of the future	Importance of HPC to government vision of the future	3.3
	Government Online Service Index, 0–1 (best)	Government Online Service Index for HPC, 0–1 (best)	0.37
	Gov't success in ICT promotion	Gov't success in HPC promotion	3.6
Economic impacts (2.7)	Impact of ICTs on new services and products	Impact of HPC on new services and products	3.8
	Impact of ICTs on new organizational models	Impact of HPC on new organizational models	3.5
	Employment in knowledge-intensive activities,% workforce	Employment in knowledge-intensive activities for HPC,% workforce	16
Social impacts (3.2)	Impact of ICTs on access to basic services	Impact of HPC on access to basic services	3.6
	ICT use and gov't efficiency	HPC use and gov't efficiency	3.9
	E-Participation Index, 0–1 (best)	E-Participation Index for HPC, 0–1 (best)	0.29

Table 3. Roadmap Strategic Areas and Their Sdri Values

No	Domains	Indicator	Value
1	Research	Skills	4.7
2	Infrastructure and Platform	Infrastructure and digital content	3
3	Technologies	Business and innovation environment	4.1
4	Regulations	Political and regulatory environment	3.4
5	Services and App	Individual usage (2.9)	2.6
		Government usage (3.4)	
6	Business	Business and innovation environment (4.1)	3.8
		Affordability (5.8)	
		Business usage (3)	
		Economic impacts (2.7)	
		Social impacts (3.2)	

Table 4. Weights And Start Time Is Considered for Strategic Domains

		Res.*	Inf.*	Tec.*	Reg.*	Ser.*	Bus.*
Proposed Roadmap	Weight	0.11	0.20	0.14	0.18	0.21	0.16
	Start	2015	2017	2018	2017	2018	2019
Roadmap1	Weight	0.2	0.2	0.2	0.1	0.1	0.2
	Start	2015	2017	2018	2017	2018	2021
Roadmap2	Weight	0.25	0.1	0.25	0.1	0.1	0.25
	Start	2015	2017	2018	2017	2019	2021

* Res.: Research, Inf.: Infrastructure, Tec.: Technology, Reg.: Regulation, Ser.: Service, Bus.: Business

7. Evaluation Results

Figure 9 compares supercomputer development roadmaps concerning their progressive rate of weights and start time. This figure shows the progressive improvement of each strategic area including research, infrastructure, technology, regulations, services and business in three stages of the roadmap proposed in Figure 8. This figure, compares the proposed roadmap with two other roadmaps considered in terms of weight and start time according to Table 4. In this figure, the progress of improvement and the year of completion in each of the strategic areas of the roadmap are shown. The start of petaflop scale supercomputer construction projects in all areas of roadmaps is 2015 according to Table 3. Based on this table, the average of the SDRI progress indicators with a value of 3.6 is considered as an initial progress value of the roadmaps. All strategic areas of the proposed roadmap will end in 2024, while the other two roadmaps will end in 2029 and 2030, respectively; because the service segment of the Roadmap 1 ends in 2029 and service segment in the Roadmap 2 ends in 2030. Therefore, overall our proposed roadmap has better speed and performance compared to other roadmaps. Figure 10 shows the progress of the SDRI index for the development of supercomputer services from the beginning of the value of 3.6 to reach the final stage of the number 7 in the proposed and two other roadmaps. These roadmaps have different conditions, according to Table 4. According to this figure, the final SDRI index in the proposed roadmap will reach the goal of reaching the value of 7 earlier; because, according to the SDRI index, which is inspired by the NRI, the final value of each index in the strategic area is to reach the number 7. The proposed roadmap will reach this target in 2024, while Roadmap 1 will reach this target in 2029 and Roadmap 2 in 2030.

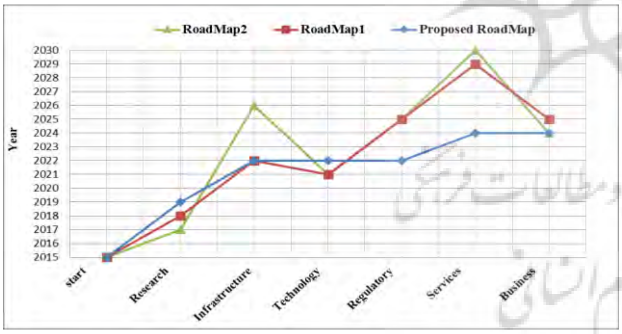

Figure. 9. Comparison of supercomputer development roadmaps with respect to their progressive rate of weights and start time

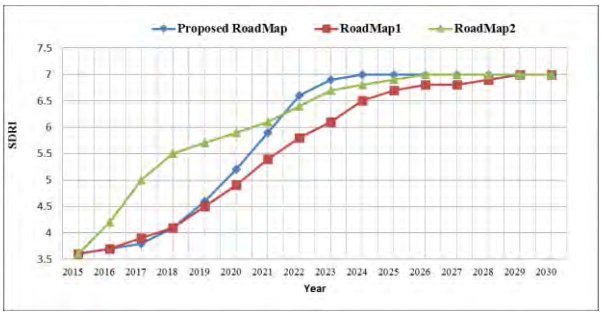

Figure. 10. Progress of the SDRI index in the three stages of the proposed roadmap for the development of supercomputing services

8. Conclusion

This article aims to design a roadmap for the expansion and development of supercomputers in the country, which provides a specific strategy for implementing HPC services. A comprehensive roadmap helps the business entity or organization to discover a new vision for future success. We proposed a roadmap that concentrates on several strategic areas, including research activities, infrastructure and platform, data processing, standard regulation, application services, and business development. The proposed roadmap, while providing a comprehensive picture of the design of HPC services in an organizational plan, provides a general solution regarding the development and expansion of this industry. The proposed roadmap was compared with other methods regarding the improvement level and timeline. The evaluation results have shown that the proposed roadmap has efficiently scheduled the strategic domains due to considering the right priorities for each strategic domain as well as considering the right starting point for each phase.

Declarations

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Authors' contributions

DM: Study design, supervision, acquisition of data. MA: Drafting the manuscript, revision of the manuscript. AM: Interpretation of the results, design, revision. EH: Analysis, revision of the manuscript.

Conflict of interest

The authors declare that there is no conflict of interest.

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