Improving Czech Digital Government Based on Quantified Maturity Model of Enterprise Architecture

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Abstract: One of the current drivers for transitioning from the traditional E-Government to the digital government is the ability to create and share new services in the governmental ICT landscape. The government must effectively communicate and offer its services to itself (G2G) and outside, be it an end-consumer or business (G2C, G2B). Since the government is internally divided, there is a need to measure its parts' performance for effective management. However, conventional maturity models cannot address and explain the cause of the differences, and thus typically respond to symptoms and show just winners and losers of the given benchmark. From this position, a study and a deeper analysis of the maturity model used in the public administration of Czechia are provided. Further analysis was undertaken via Bayesian networks to answer the question: How do project management and prioritization affect service level management? Or how the enterprise architecture as a method is linked to the overall organization's performance? Significant relationships were identified, and the use of the Bayesian network as a prediction model was proposed. Further evaluation steps and research opportunities were discussed.

1 INTRODUCTION

The main goal of the presented paper is to obtain and compare the capabilities of individual public authorities. Comparison is made from the viewpoint of the National Architecture of the Czech Republic. This overview of the current state of the scope of capabilities of individual actors of public administration is a suitable but also a necessary starting point for the design of sustainable other concepts, solutions, and development of national architecture. Ultimately, national architecture is the result of the cooperation of all individual actors.

Among the current problems of deploying and maintaining corporate architecture in the public sector are considered causes such as the resistance of individual authorities to corporate architecture and the division of roles, setting relevant goals, and the issue of using corporate architecture in practice. A partial problem pertinent to this area is the need for a link between qualitative and quantitative data. Also, specialized and expert experience and skills are insufficient to manage complex systems (Seppänen et al., 2018). Al-Kharusi et al. (2018), in a qualitative case study of the public sector of Oman, elaborates in-depth on the genesis of the creation of enterprise architecture, in which the level of knowledge of stakeholders and its sharing plays a key role.

2 THEORETICAL BACKGROUNDS

Regarding the current state of maturity models, two approaches predominate, or domain-specific meta-models of maturity, for example, as Ostadzadeh and Shams (2014) have shown in a study of highly complex and interconnected systems for which general meta-models were insufficient.

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As Santos-Neto and Costa (2019) introduced, there is also an exciting trend where many models are created, but only a part of them is validated and applied.

2.1 Czech e-Government

From the point of view of the development of enterprise architecture in the public administration of the Czech Republic (Czechia), four years have passed since the first significant standardization processes commenced. These changes were driven by the program Digital Czechia (Digitální Česko) (Czechia, 2018b) and strategically mainly with the Information Strategy of the Czech Republic and its annexes (Czechia, 2018a).

The annexes: National Architectural Framework (NAF) and the National Architectural Plan (NAP), are the backbone for the objectives of Digital Czechia. This standardization follows the reforms and concepts of managing the architecture of the public administration as Hrabě (2013) presented in its work.

One of the central architectural governance bodies is the Department of the E-Government Chief Architect of the Ministry of the Interior of the Czech Republic (shortened as DECA). DECA is also responsible for approving ICT projects in the public sector of Czechia.

2.1.1 Context of EU

The European Union has presented its framework for measuring the maturity of service interoperability across the members of the European Union (EU & Mannot, 2016). The NAF acknowledges this framework. However, the scope of the interoperability framework is narrow, and usage is limited. Currently, NAF includes the Benchmark of Public Administration. However, that is a change made in the past year. Up to that point, the NAF included only brief subjective self-assessments based on eight capabilities for managing an organization's enterprise architecture, and the rest referenced TOGAF (DECA, 2021).

As the TOGAF to this day does not contain its maturity model, the reference was and still is a proxy for the maturity models of the third parties (The Open Group, 2019, 2022).

Another approach to measuring maturity in the context of the European Union is The Digital Economy and Society Index (DESI). DESI can be used to ascertain Europe's overall digital performance and the digital competitiveness of the corresponding countries. DESI is a composite index of five underlying categories (European Commission, 2022).

Looking at the relative position of countries, Czechia is still underperforming and put behind the average EU values. Moreover, Czechia is lacking in digital public services.

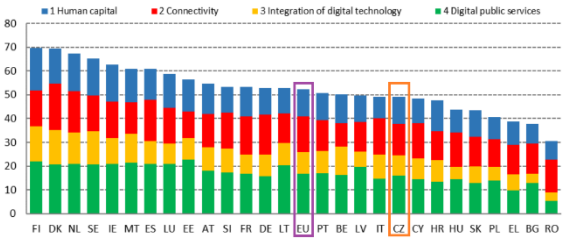

Figure 1: DESI 2022 – and position of the Czechia (European Commission, 2022).

2.2 Quantifying the Performance

The underlying problematization of given maturity models lies in their explainability – with basic questions such as: What is the cause? Why it works that way? Conventional maturity models cannot address and explain the reason for the differences. Thus, typically respond to symptoms and show just winners or losers of the given benchmark, where the low-performing areas of the organization would be targeted for improvement, but the real cause would remain hidden.

From this position, the need for study and a deeper analysis of the maturity model arises. Explainability further raises the ambitions for internal quantitative improvement based on additional quantification and structuring of variables. This approach is performed in the case study of the Czech digital government (E-Government). This further analysis was achieved via Bayesian networks, theoretically described in the next chapter.

3 MATERIALS AND METHODS

This section introduces the primary data sources and their processing methods. Firstly, the Benchmark of the public administration of Czechia is described. Then the approach of using Bayesian networks is presented

3.1 Czech Benchmark of Public Administration

The Benchmark of Public Administration, also known as the ICT Benchmark of Public Administration, is

Figure 2: Overall Maturity Level Dynamics – Change from 2018 to 2021. M(x) is an anonymized ministry, ÚSÚ(x) stands for anonymized central administrative authority. Maturity could range from 1 to 5.

conducted every three years and is based on the Digital Czechia program (Dzurilla et al., 2018). In this paper, the Benchmark of the Public The administration will be called "Benchmark". The Benchmark focuses on three main areas: a) Public administration management, b) Finance and personnel situation, c) Subjective evaluation of the Czech public administration and E-Government.

Each of these areas is broken down in more detail into individual questions. The first Benchmark took place towards the end of 2018. The second Benchmark took place towards the end of 2021.

In terms of a scientific viewpoint, this Benchmark is a domain-specific maturity model tailored for the public sector, particularly the corresponding legislation. This domain-specific approach is justified, as Ostadzadeh & Shams (2014) showed in a specific information system case study. In the case of the complexity of public administrations and their systems, the complexity will be higher. Of course, this domain specificity is redeemed by a reduction in interoperability. Thus, the possibility of ad-hoc comparison of the different systems. It is important to note that multiple domain-specific maturity models are created; however, only a fraction is validated and used (Santos-Neto & Costa, 2019).

The motivation for applying robust inference techniques is to gain insight into the structure of the issues or the concepts behind them. This could be used to overview where knowledge needs to be added or used correctly. Thus, it is a step forward in creating and maintaining a functional enterprise architecture approach (Al-Kharusi et al., 2018), but also the possibility to create target points/states and find scenarios that best support or even enable them.

An extensive benchmark was carried out from the end of 2018. This Benchmark included all 14 ministries of the Czech Republic and 20 central administrative authorities (CAA for short).

In 2021, a second iteration of the Benchmark took place where we, as the authors, were part of the Benchmark team. Again, all the ministries were surveyed. The overview of the Benchmark 2018 and Benchmark 2021 can be seen below. In this paper, we further explore the first and three main areas of benchmarking: Level of governance, Level of change management, and ICT level of governance and capabilities.

Table 1: Overview of the used Benchmark 2018 and Benchmark 2021 datasets.

Benchmark	2018	2021
Number of organizations	14 ministries, 20 CAA	14 ministries, 20 CAA (7 rotated)
Timeframe	June to August 2018	October to November 2021
Data collection	Semi-structured panel interview with the questionnaire	Semi-structured panel interview with the questionnaire
Variables	40 (as factors)	38 (as factors)

3.2 Methods and Bayesian Networks

Firstly, the questionnaire data were evaluated using descriptive statistics, namely sample means and frequencies. As all forms were completed and no gross errors were found, all the data were deemed valid and were further used in the creation of the Bayesian network.

Table 2: Mapping the code questions/variables of the Benchmark 2021 and harmonized Benchmark 2018.

Code	Question/variables
x0	<Dummy variable> - ministry (1), central administrative authority (0)
x1.1	Relevance and quality of the organization's strategy (existence and use of the Information Strategy)
x1.2.1	Up-to-date catalog of services and actions for citizens and companies (according to Law 12/2020 Coll.)
x1.2.2	Does a customer service manager exist to manage client services and service channels of the ministry/authority (counters, e-filing, data boxes, a portal of the ministry/authority) across agendas?
x1.3	Your organization's management system, hierarchical vs. procedural management
x1.4.1	Degree and method of digitalization of agendas
x1.4.2	Degree and method of digitalization of support/operational processes (budgeting, human resources...)
x1.4.3	Degree and method of digitalization of management processes (planning, concept management, quality…
x1.5.1	Level of quality/excellence management and feedback
x1.5.2	Level of risk management
x2.1.1	Do you have a Digital Champion? (This is not a formal position of the Digital ambassador)
x2.2	ICT's position and mandate in the organization's management system
x2.3.1	How is Enterprise Architecture (EA) maintained and used as a management method in the organization to support strategic planning and change management?
x2.3.2	Does the organization have its own internal Enterprise Architect?
x2.3.3	Are the new systems, or changes to systems, always approved by the unit of the Enterprise Architecture?
x2.4.1	How is project and program management used to deliver successful organizational change?
x2.4.2	Does the organization have project managers?
x2.4.3	Is a process for recording and prioritizing projects across the organization defined and used?
x2.4.4	Is there a dedicated (planned) capacity of systematized posts (or part-time posts) within the organization to implement change (for inclusion in projects)?
x2.4.5	Is a process in place and routinely used to dedicate/release internal experts to projects and replace their missing capacity in the line management of the organization's performance?
x3.1	Level of management of the information strategy
x3.2	Level of implementation of requirements management and its flow from the business to the ICT departments
x3.3	The current catalog of internal IT services
x3.4	Service management in place (SLAs on all key systems, both to internal customers and external suppliers)
x3.5.1	How have you addressed the integration of security policies into IT processes and procedures for the design, implementation, operation, and use of IT solutions
x3.5.2	Have you implemented and actively used SIEM (Security Information and Event Management)?
x3.6.1	IT quality system in general
x3.7.1	Do you measure the cost per end-user transaction?
x3.7.2	Do you measure the successful and unsuccessful completion of transactions?
x3.7.3	Do you measure user satisfaction with the application/system?
x3.7.4	Are you measuring the usage of the digital channel versus the non-digital channel? (Where meaningful)
x3.8	The ability of the IT department to design the system, tender, and deliver on time with a given quality
x3.9	The ability of the Authority / IT Department to operate the systems and measure the quality of operation.
x3.10.1	Do you use the software provided as an external service (SaaS)?
x3.10.2	Do you use cloud solutions (running systems as a service, PaaS, IaaS)
x3.11.1	Do you have the source code for custom solutions and custom modifications to stand-alone software for all critical IT solutions (primarily the legal category of public administration information systems)?
x3.11.2	Do you have development documentation (e.g., detailed data model) for all critical IT solutions?
x3.11.3	Do you have contractually secured licensing rights to maintain and develop IT solutions?
x3.11.4	Have you secured in-house competence (capacity and knowledge) to maintain and develop the organizations' key platforms and solutions (for each solution accounting for at least 10% of the organizations' IT spend)?

In addition to descriptive statistics, which typically speak about the state, distribution, and frequencies of the concepts under study, we wanted to move within the knowledge modeling to a state that would allow us to grasp the internal dependencies and predict the conditions of individual ministries and authorities. For this purpose, the approach of Bayesian statistics and its Application using Bayesian networks based on artificial intelligence and machine learning was used.

The Bayesian network is a multidimensional method that, in addition to the objectives defined above, is user-friendly as part of its result is a visualized graph (Jensen, 2001; Koller & Friedman, 2009). This graph can be imagined as a map of the relationships between sub-constructs (variable), such

as how a digital service uses the computing power of the underlying servers and how these services relate to the existing catalog of IT services. Simply put, the network helps us find links between issues that would not otherwise be visible.

The resulting Bayesian network can thus be seen as a model that allows:

- Define the internal structure of the data.
- Analyse the probability distribution of the data.
- Predict data states of interest based on known other related information.

The Bayesian network was used for the underlying structure of the research concepts as a learning algorithm has used a variety of score-based (Hill-climb, tabu search) and constrain-based (pc-stable, grow-shrink) suitable algorithms implemented in the bnlearn (Scutari, 2018). For ascertaining, the statistical significance chi-square test was used, and for measuring the strength of the relationship, the criterium of Mutual Information was used. Both those metrics were based on the $\alpha = 5\%$, with a 95% confidence interval. The Bayesian information criterion (BIC) was used for the overall model quality evaluation (Jensen, 2001; Koller & Friedman, 2009). The algorithms were realized based on the bnlearn package for R Scutari (2010).

4 RESULTS AND DISCUSSION

The input to the model to obtain the Bayesian network was 34 vectors, all with 39 variables per vector. There were no missing values. Given this number of ministries and agencies surveyed, score-based gradient algorithms performed well, whereby the best model was then selected based on BIC. Final Bayesian networks are computed via the Hill-Climb algorithm.

All relationships in the models are statistically significant, where the mutual information parameter, as was already mentioned, was used to classify and determine the strength of the arc. The direction of the arcs is defined based on internal network consistency criteria. It thus cannot be considered as the direction of causality, although it may be consistent with it. The final model based on data from Benchmark 2021 contains three mutually disjoint Bayesian networks, two of which are trivial, containing a maximum of three elements. The last network includes a structure of 21 nodes and 20 arcs. Due to the limited data set, the created model is a tree (graph theory). We refer to this Bayesian network as the “main network”.

No significant statistical relationships were found between the ten questions (variables), so they are not part of any of the networks mentioned in the model.

Let's analyze concrete questions such as question x1.2.1 by looking at the answers, especially for the ministries. We can see a possible pressure to answer, corresponding to a clearly given legislative obligation. This aspect of "not admitting weakness and staying in the grey middle" needs to be considered when assessing this Benchmark.

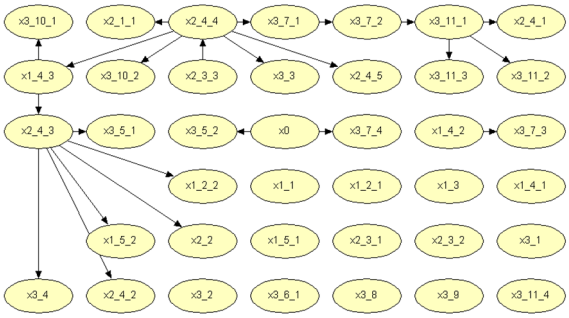

Figure 3: Model created from Benchmark 2021 data set.

A different perspective is offered when considering question 2.3.1, “How is Enterprise Architecture (EA) maintained and used as a management method…” as this variable is independent and not connected to any network.

This result indicates that the level of exercising enterprise architecture does not bring a good effect, as not even the dummy variable (x0) of the overall maturity level is independent. This situation could be explained as the enterprise architecture approach has still failed to be adopted in today's public administration of Czechia. The purpose of enterprise architecture is the effective holistic management of an organization.

Unfortunately, the current situation corresponds to a situation where these thoughts are tightly linked only to information systems. However, EA is not an ICT discipline, although it is historically tied to it. The situation where this approach is used from an ICT direction is better than if it did not exist, but it is not meant to be so. If this current ICT stigma were removed and enterprise architecture departments had access to ICT and non-ICT management and change, the potential for effective functioning of single public administration actors and their digital services would be multiplied many times over.

4.1 Difference Between Ministries and Central Administrative Authorities

Adding an auxiliary variable defining whether an organization is a ministry or a CAA, we learn that only two variables are affected by this division.

The first of these behavioral differences is using SIEM, one of the main tools for managing cybersecurity and, thus, the reliable operation of public administration. In terms of ministries, all but one ministry used SIEM. The split in the central administrative authorities is 60:40 in favor of using SIEM. However, this situation cannot be considered satisfactory; one of the priorities for the secure functioning of the public administration would be to roll out the already existing SIEM solutions to the area of the UAS concerned and to introduce this system unconditionally to the remaining ministries.

The second noticeable difference is the representation of the measurement of the use of the digital channel for services versus the non-digital channel. Here, there are situations where the CCA either excels (45%) or does virtually nothing (also 45%), with the remaining 10% (two CCA) of the organizations surveyed falling somewhere in between.

Looking at ministries, which are generally larger, only one ministry indicates that it does so for all meaningful activities. Most ministries (56%) need to practice this measurement and evaluation. The remainder, about a third of ministries, indicate that measurement occurs when there is increased interest, i.e., not routinely but systematically as needed. However, measurement and evaluation are principles of compiling and maintaining a catalog of digital services, including planning new ones based on user knowledge and thus facilitating the digitization of such services.

4.2 The Second Bayesian Network

As another very trivial Bayesian network, the relationship between the degree and manner of digitalization of operational processes (question 1.4.2) and the measurement of user satisfaction with the application/system is presented. In this condition, a positive relationship is observed, where the probability of measuring user satisfaction increases with an increasing degree of digitalization of operational processes.

The resulting model did not further connect this network to other elements or directly to other networks, but by looking deeper into the data structure, a subjective connection, or hints of it, can be found, at least with the other questions of the service/transaction measurement capability topics (3.7.1, 3.7.2). In the case of a more significant number of data, this connection with other elements/networks could be statistically confirmed based on the chosen model criteria.

4.3 The Main Bayesian Network

The leading Bayesian network consists of 21 variables (maturity model questions). It can be noticed that its visual structure corresponds to the system of primary elements and the fans that branch from them. Questions 2.4.4 examining how the organization plans and allocates its internal capacities, 2.4.3 concerning the definition and prioritization of projects, or 3.11.1 whether the organization has solution source codes can be considered as the main elements through which the remaining others are linked.

Let us consider the last-mentioned element, i.e., the role of source codes in ICT solutions. The graph shows that this element is statistically related to the other four elements (questions 3.7.2, 2.4.1, 3.11.2, 3.11.3). If we mentally try to derive how the source code solution will be related to the ownership of the access documentation, it makes sense to have both approaches at the same or similar level. It makes no practical sense to have access to source code but no longer to development documentation and vice versa.

Table 3: Conditional probability between the maturity of questions 3.11.1 and 3.11.2.

		3.11.1		
	maturity	1	3	5
3.11.2	1	0.75	0.07	0.00
	3	0.25	0.87	0.40
	5	0.00	0.07	0.60

A look at the probability ranking between the two elements gives us the right idea. The most likely situations are on the main diagonal (both maturities at levels 1, 2, or 3). With that said, a relationship where one maturity is at level 1 and the other at level 5 does not occur.

The statement presented above could have been more interesting. We had such an assumption beforehand, so the result could be considered obvious. If we now disregard the situation where this "obviousness" is detrimental, we do get another, a more fundamental piece of information. The model behaves as we expect it to, i.e., the validity of the approach is substantively demonstrated in this case. The following sections will discuss only the conceptual, possibly surprising implications.

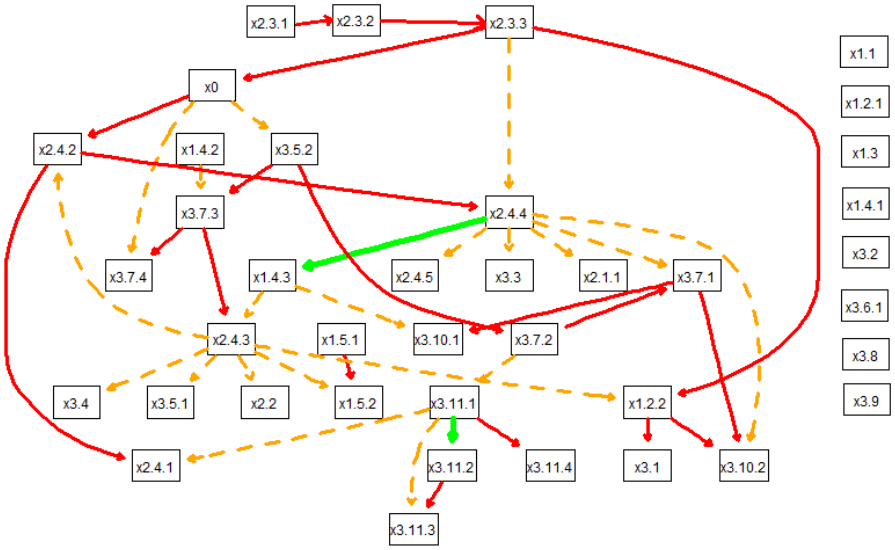

Figure 4: Bayesian Network Comparison Between Benchmark 2021 and Benchmark 2018.

4.3.1 Use of Software in the Form of SaaS and Cloud Solutions

It is interesting that the two cloud questions (3.10.1, 3.10.2) are not together but are re-allocated to internal management question 1.4.3 - The extent and manner of digitalization of management processes..., and question 2.4.4 - Is there a dedicated (planned) capacity of systemized posts in the organization for implementing change? Thus, under this assumption, the way of using software such as SaaS and cloud solutions are independent, given 1.4.3 or 2.2.4.

Those who can effectively plan and structure internal capacity are able to use cloud solutions. The reverse direction of the relationship is meaningless here since the ability to delegate and compartmentalize is independent of how the technology is implemented. Conversely, of those who do not have this capability, only one in two use cloud technologies. Thus, with the progressive digitization of management pro-processes, the ability to use the cloud can be influenced by activating and enhancing the internal capacity planning capabilities. A more in-depth analysis of the management of the organizations in question would be needed to determine what the specific steps should be. However, in the first approach, the incremental differences (deltas) between levels (maturity) can be based on the answers obtained.

4.3.2 Prediction Capability

Suppose we are interested in how the level of the service level management (3.4) is influenced by the capability of the management of projects (2.4.3).

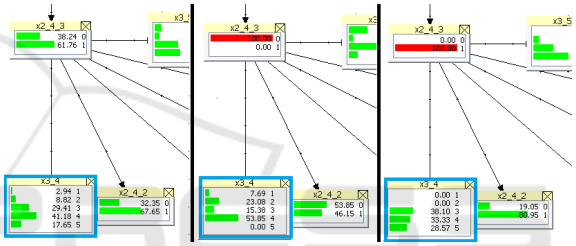

Figure 5: Main Bayesian Network – 2.4.3 Cut-Out.

As can be seen, there is a tight relationship. If the capability is absent, the maturity level of 3.4 is more spread and does not achieve the highest maturity. In contrast, setting the evidence for 2.4.3 that the organization's project management with prioritization is exercised results in a higher chance for higher maturity levels (Figure 5).

4.3.3 Comparison with the Benchmark 2018

For the comparison between 2021 and 2018, the source data had to be harmonized first. Benchmark 2018 was harmonized to be comparable to Benchmark 2021. The changes for Benchmark 2018 included removing or aggregating different questions.

By comparison, only two links have been completely preserved (Figure 4, green relationships). For the other nodes, there are changes (orange is present in the Bayesian network from Benchmark 2021, and red arcs are present only in the Bayesian network from Benchmark 2018). This difference can be demonstrated by the already discussed usage of the SIEM (question 3.5.2). Looking at the underlying data of 2018, there was no difference between

ministries and CAA. Ministries have acted, and almost all of them have integrated the SIEM solution. This overall significant difference between networks calls for further exploration.

5 CONCLUSIONS

This paper addressed the quantification of relationships within a standardized public administration benchmark. Machine learning-based Bayesian networks were used as a tool for this quantification. Bayesian networks combine both visual simplicity and explanatory and predictive power. Also, the demonstrated approach is generalizable.

By understanding the structure, strategic decisions can be better directed, and processes of digitalization and further development of the Czech public administration can be made more efficient.

Further examination of the dataset and the Bayesian network could bring more exciting findings than those presented in this short paper. Also, applying different approaches to aggregating the data will enable different views on the matter. Moreover, applying the leave-one-out cross-validation (Efron, 1982) for the presented model or constructing and comparing more Bayesian network models could be performed. A deeper evaluation of the differences and their causes between Benchmark 2021 and Benchmark 2018 could be another future topic.

Last but not least, insight could be gained with the incorporation of the rest of the Benchmark available data. The challenge would be making a hybrid network with not just factor variables but also numeric ones. As authors, we are excited about the next Benchmark from the public administration of Czechia and the possibility of further improving the Czech Digital government.

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