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How Artificial Intelligence and Design Thinking can Benefit from each other?

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Abstract—Artificial Intelligence (AI) and Design Thinking (DT), despite they emerge from different scientific disciplines, are increasingly associated with each other. In this article, the fundamental similarities between the two concepts are discussed and it is therefore demonstrated how the two fields can benefit from each other. AI can functionally activate innovation practices in DT; and DT approach can help ensure the fundamental way that create AI ideas and useful automated-application that adequately solve problems facing consumers. This overlap is illustrated by two Tunisian case studies which points respectively the two contributions. Some implications for design and innovation management scholars and practitioners are discussed.

Keywords : Artificial Intelligent, Design Thinking, Marketing Innovation, Learning, Marketing research, case study.

I. INTRODUCTION

In the era of connected objects and the processing of massive amounts of data, we have an unprecedented amount of information about how people use different goods and services (Cockburn et al., 2018; Kakatkar et al., 2020). Artificial Intelligence (AI), thanks to algorithms, has revolutionized our daily lives through useful automated-oriented applications and in multiple facets: Robotics, Deep Learning, Machine Learning, Big Data Analytics, etc. Yet, as important as, AI has also changed the innovation process itself, with potential deep management transformations (Cockburn et al., 2018).

Funded since 1955 at Dartmouth College in Hanover, AI allows due to their new approaches and renewed funding in the 21st Century, reducing the processing time of the incredible mass of data (Liu et al., 2018). We are today able to capture, and gives us the possibility of synthesizing, forecasting or recommending with increased reliability from a volume data that would be humanly difficult to process (Kakatkar et al., 2020). Automatic analyzes of suppliers or competitors for more efficient sourcing; increasingly relevant alternative or complementary product proposals; emotion analysis to assess the impact of a service or a product, or even the analysis of business processes for their automation, using "intelligent assistants". This revolution has provided an entirely new way of thinking that goes well beyond AI (Lungarella et al., 2007), to include the philosophy of Design Thinking.

At the core of any technologies' innovation lies a fundamental practice : the way people create ideas and solve problems (Verganti et al., 2020). Born in the 1980s at Stanford University, Design Thinking (DT) is an innovation management method that relies on a non-linear approach to collaborative design (Reinecke, 2016; Lee et al., 2020). It aims to enable companies to innovate by drawing inspiration from the way designers think (Lee et al., 2020). Because it is collaborative and human-centered, it is back in vogue (Lee et al., 2020). Today, a growing number of companies, universities and consulting firms use DT, continuously enlarging and re-defining its meaning (Brenner et al., 2016).

Even though AI and DT have different sciences origins, the intersection between the two areas is to be highly valued. AI continually injects data and algorithms into the heart of innovation processes, and this later increasingly call to be closer to human design and his inherently activity of sense-making (Verganti et al., 2020). While DT is still strongly influenced by the innovation diffusion and engineering culture (Reinecke, 2016), AI is often dependant to a deep understanding of design's paradigm and principles (Verganti et al., 2020).

Previous research has mainly focused on studying the impact of AI on DT practices and the changes that DT has undergone as a result of integrating AI (Eppler and Kernbach, 2016; Cautela et al., 2019; Verganti et al., 2020). However, the examination of DT contributions to AI has not yet been well valued. This requires a deeper understanding of the benefits of DT and its practices for development and implementation of disruptive technology. What is the impact of DT on AI ? What are the implications of the future-oriented innovative method of DT for our proof understanding of digital technology? Is DT process will still significantly contribute to solve obvious and hidden needs of AI's users? Or will it enlarging its meaning to sufficiently capture current theoretical frameworks of innovation of digital technology?

This paper proposes a framework for understanding the overlap between the design process and disruptive technologies such as AI. We will explain on the one hand, the methods and tools of AI that could be used to enrich DT process. On the other hand, we will explore how DT can allow cutting-edge technologies to express their full potential.

In the real business world as well as in the literature, we still ignore the existing number and the impact of DT

applications in AI. This is the literature gap at the interplay between DT and AI that this article aims to partially cover, thus motivating the undertaking of an exploratory research focused on Tunisian context startups that offer AI-base service for DT proposed in the following. Our theoretical ideas are illustrated by two cases which indicate respectively the two reciprocal directions studied for the evolution of design and innovation in companies.

II. THEORETICAL BACKGROUND

AI and DT are concepts that has is intensively examined by their academic science, in a multitude of scientific books, journals, conferences, management talks and consulting firm offers. A closer examination reveals a lack of clarity about their joint, their common elements and how they can benefit from each other.

Examining the definitions of AI and DT, however, there are surprisingly similarities and intersections. Brown (2008, p. 86) defines DT, as “a discipline that uses the designer’s sensibility and methods to match people’s needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity”.

Artificial intelligence (AI), commonly defined as “a system’s ability to interpret external data correctly, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation.” (Haenlein and Kaplan, 2019). By its evolutionary stage, AI can be classified into analytical, human-inspired, and humanized AI depending on the types of intelligence it exhibits (cognitive, emotional, and social intelligence) (Haenlein and Kaplan, 2019; Verganti et al., 2020).

If we combine these two definitions, central common aspects of AI and DT are revealed. DT starts with human needs and uses suitable technologies with the aim of creating management value through customer value. Indeed, AI uses flexible learning from data to achieve specific goals through adaptation to centric-human needs.

Following an exhaustive review of the literature conducted by analyzing the main scientific studies (in design and management science on the one hand, and in AI science on another hand), associated with an exercise of filtering and comparison between the two sciences; key concepts, principles, methods and tools have been identified.

1) *Similarities and intersection between the two areas*

In this article, in order to study the intersection between the two fields and to connect the similarities’ points of AI solutions with DT principles, we use the main DT attribute’s identified by Micheli et al. (2019), and re-used by Cautela et al. (2019) in their study of the impact of AI on DT practices.

- **Human orientation and user-centeredness**

Human orientation is a major paradigm in DT (Brenner et al., 2016). Thus, DT is based on a sociological foundation by strongly associating the “human-centered” attribute with the

DT approach (Reinecke, 2016). This human orientation attribute opens many interfaces for AI, which relies also heavily on insights from psychology and sociology in the field of consumer behavior (Lungarella et al., 2007). For examples, in its sub-domain, Machine Learning make inferences and decisions based on past human experiences, Neural Networks work on Human centered approach to give the similar principles as of Human Neural cells, Language Processing is a machine that understands the human communications and it responds accordingly (Lungarella et al., 2007).

The new approach to understanding intelligence has led to this paradigm of user-centeredness which emphasizes the physical and information-theoretical implications of embodied adaptive behavior: Intelligence requires a complete physical organism interacting with the real world: The focus in this new paradigm is on systems acting in the real, physical and social world (Dautenhahn, 2007).

- **Innovation and creativity**

DT “is fundamentally concerned with developing creative or original responses” (Lee et al., 2020, p...). Focusing in design in whole company “design thinking is a way of thinking that fosters creativity and innovation in products and services, as well as new approaches to business and organization” (Lafley et al., 2013, p.5). In enchainment with the previous similarity, Lockwood (2010b, p. 5) states that DT is “a human-centered innovation process”.

It encapsulates the cognitive strategies and behaviors of people who are engaged in developing innovative solutions to problems, or identifying new opportunities in a complex marketplace or ecosystem.

AI is the invention that enables innovation across many applications. AI is defined “as the ability of a machine to perform cognitive functions similar to human minds, such as exercising creativity” (Ref, p.). Innovation and creativity in AI are not only new technologies applications, but rather may be incentives of future purpose technologies. As it is true neural network is an advanced of deep learning (Cockburn et al., 2018).

Indeed, each academic research dealing with DT, as well as AI refers to creativity and innovation, and these aspects are often reported as the essence of process (Michelli et al., 2019). Innovation and creativity are fostered by cultural diversity and by the involvement of the multiple perspectives that co-habit an organizational context (Cautela et al., 2019).

Arguably, AI can play the role of creative enabler and partner of the innovation manager across the data-driven innovation process (Kakatkar et al., 2020).

- **Interdisciplinary collaboration**

Another similarity that AI and DT have in common is their multidisciplinary nature. DT is an interdisciplinary process which lies more in the areas of mechanical engineering, product design and innovation management (Reinecke, 2016). However, multidiscipline in DT is not limited to functions, but also integrates ability profiles of various team members: cross-disciplinary collaborative teams (Reinecke, 2016; Micheli et al., 2019; Lee et al., 2020).

To leverage collective intelligence in the design process, team building and task assignment in DT are governed by the involvement of cross-disciplinary teams (Brown, 2009; Kelley and Kelley, 2013; Lee et al., 2020). Similarly, the issues of cross-disciplinarily collaboration are also clearly marked in AI (Lungarella et al., 2007). The trend appears to be an expansion of AI into a wider area as a result of the connections between body, brain and environment (Lungarella et al., 2007). Therefore, in addition to mathematical logic, engineering and computer science, other research disciplines contributing to AI are philosophy, psychology, automation, robotics, linguistics, biomechanics, artificial life, adaptive locomotion, bio-inspired systems, and neuro-informatics or neuroscience (Lungarella et al., 2007).

• **Solve problem and find solution**

Both DT and AI are ultimately geared to develop innovative solutions to human problems. DT has been widely considered a means of solving problems, particularly “real-world” or “wicked” ones such as ecological dilemmas, economic crises and resource shortages (Buchanan, 1992; Lee et al., 2020). As far as, AI allows providing novel ways of approaching technological, social, and economic problems in the rapidly changing world of the 21st century (Lungarella et al., 2007). Kakatkar et al. (2020) demonstrates for innovation analytics that a problem can be defined as the unmet need of a given stakeholder. A solution is the tangible or intangible innovation that can solve a given problem.

Looking at business problems in particular, several examples AI technologies such as robotics, computer vision, language processing, chatbot, and machine Learning that enable to solve management constraints (e.g. market demands, achieving operational efficiency) (Kakatkar et al., 2020). AI is indeed a multiple purpose technology: as a matter of fact, its domain mostly embraces multiple solutions and even heterogeneous methodologies to accomplish many tasks in relation to different organizational departments across many industries (e.g. retailing, banking, tourism) (Cautela et al., 2019; Kakatkar et al., 2020).

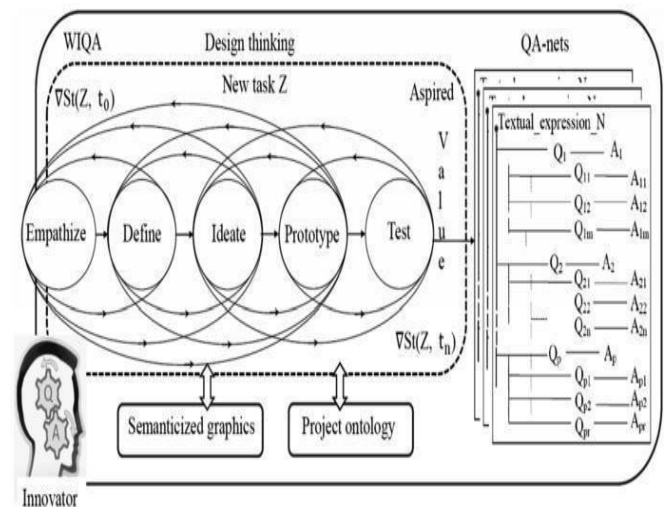
• **Iteration and experimentation**

DT has been described as an iterative and non-linear process (Micheli et al., 2019), including spiraling off-ramps and intricate intersections (Lee et al., 2020), and characterized by trial-and-error learning (Beverland et al., 2015). By focusing on DT's approach, we identify several forms of iteration in the literature: the interplay between a “deductive and inductive” approach (Martin, 2009; Cautela et al., 2019), “framing and reframing” of the problem-context (Drews, 2009), “divergent and convergent” approach (Lee et al., 2020) and the continuous interplaying between the “problem-space” and the “solution-space” (Dorst and Cross, 2001). For AI in the innovation process, the “convergence-divergence” dynamic that spans problems and solutions is widely applicable to innovation analytics valorized by Kakatkar et al. (2020) as a “double diamond”. In the context of AI companies, Verganti et al. (2020) noted a specific solution of

“problem-solving loops.”, that is, what an individual user actually interacts with, is designed by an AI engine.

2) **Artificial Intelligence Contribution's to Design Thinking**

AI can play an important role in the DT process, from the exploration of problems to the selection of solutions (Sosnin, 2018; Kakatkar et al., 2020). Indeed, the computational platforms and digital applications of AI are one of most powerful resources for DT (Sosnin, 2018, Kee et al., 2020). To the point that Sosnin (2018) presents a version of automating the DT approach oriented on innovatively personified projects (cf. Figure 1). These digital design environments support automated question-answer interactions, rapid modeling, testing and evaluation of alternative options. They also enable the development of enhanced cognitive strategies and skills (Sosnin, 2018; Kee et al., 2020).



More recent studies, such as Cautela et al. (2019) and Verganti et al. (2020), highlighted the role of AI in supporting and empowered DT, and moreover they demonstrated which phases of DT are mostly benefiting from AI solutions.

• **Empathize**

This step requires a deep understanding of human’s needs (Reinecke, 2016). Yet, the design and analysis methods used by marketing researchers have evolved considerably in recent decades thanks to AI and its family innovation such as Machine Learning (ML), Big Data, Data Analytics and Neural Networking (Chan et al., 2018; Hair et al., 2018).

AI applications lead to a deepening of empathy in this phase by creating personas and storytelling more quickly and perfectly focusing on the needs and experiences of real people (Hair et al. 2018; Cautela et al., 2019). Therefore, AI has the ability to provide sense to massive amounts of data in near real-time, to improve data quality and to provide powerful analytics, easier to use, and more widely used (Sosnin, 2018). Moreover, AI has the ability to provide sense with the user (e.g. extracting a set of significant concepts from useful facts,

discovering such relationships from the the extracting concepts) (Sosnin, 2018; Caulela et al., 2019). Indeed, when user analysis is deal according to the various AI techniques of user observation, ethnographic research, contextual inquiry and interviews, further collecting information and insights on the problem context and developing sensing and empathy with the user (Cautela et al., 2019).

Therefore, it becomes clear that the deepening potential of DT regarding empathizing will grow strongly with the ongoing involved of AI.

- **Define**

It this phase is important to clearly and well-formulate the unique problem (Liu and lu, 2019). To do this, a process of understanding collected data, challenges with particular areas and holistic barrier is implemented. In disruptive technologies area, AI is changing the farming and reframing practices of defining problem (Cautela et al., 2019). When the problem is framed, alternative ideas will be sought to achieve a reframing of the problem.

Cautelat et al. (2019) explained how AI pattern discovery application can be dramatically useful in increasing the understanding of the problem-space. In lights with intelligent data processing; this algorithm solution can be useful in farming problems which allows processing structured and unstructured data to extract information from raw data (Sosnin, 2018). These applications may include "predictive analytics", since the applications analyze data to predict future events or phenomena; and the "discovery of models" following the spreading of the framing and the relationships between different types of raw data (Cautelat et al., 2019).

Moreover, when it comes to applications of AI algorithms, the DT teams have better clarity and can align themselves easily to take the right decisions in defining problem.

- **Ideation**

In this core phase, professionals would enhance their thinking alternatives and widen their choice options, leading to a better solution (Reinecke, 2016). AI has increasing contributes in ideation sessions of DT, alternate with intelligent techniques for idea generation, collaborative sketching and reflection for decision making (Chen et al., 2019). AI and data mining techniques are recently implemented for enhancing design ideation. Based on computational creativity theory, semantic ideation network generates new ideas by integration of mining potential knowledge connections across various knowledge domains (Sosnin, 2018; Chen et al., 2019). Disruptive technologies can advance the ideation process quickly and easily in terms of quantity and novelty, especially, an intelligent remove from problem space into solution space. In addition, professionals are associated with the ways computational platforms can be used to support collaboration and to leverage collective intelligence in the design process.

- **Prototype**

Creating and testing a full-blown model of the AI solution is a time-consuming process. Rather, creating a few

prototypes and test them for improvements are an intelligent design thinking ideology. All prototypes are working models that demonstrate unique capabilities towards solving the identified AI problem.

Prototyping is the best way to save time and effort on any lapse or error found on this stage. If one prototype does not make the cut, we can move to the other and test it. This is how we can select the best prototype and scale it to a full-fledge AI model. The risk of launching the AI solution developed without going through the design process is much higher. By prototyping, companies can reduce this risk multifold.

The design of a product or service implies making a number of highly sophisticated and conceptual decisions. Especially during development, these decisions require specific problem-solving skills. Examples of these detailed decisions are the choice of the functional shape of an object, the details of a product interface, or which information to display on a screen. There are plenty of detailed problems to be addressed during design. AI offers the intelligence to solve those (Verganti et al., 2020).

- **Test**

Once the team selects the successful prototype, they can implement the final AI solution. The last step includes rigorous testing on the algorithm and the overall AI technology being implemented to make it more efficient and accurate. Whether the solution solves a functional problem or an enterprise-level issue, the overall approach will still be the same. Only the magnitude of the problem and efforts and the overall impact would differ.

After the level one testing and bug fixing, revisit phase 1 is to rethink the problem from an empathetic perspective. This helps in making necessary AI fixes to make the deployed AI solution fool-proof. Repeat this step multiple times.

In sum, AI thus reinforces the principles of Design Thinking, namely: being people-centered, abductive, and iterative. In fact, AI enables the creation of solutions that are more highly user centered than human-based approaches (i.e., to an extreme level of granularity, designed for every single person); that are potentially more creative; and that are continuously updated through learning iterations across the entire product life cycle (Verganti et al., 2020).

The algorithms embedded in these loops think in a radically different way than a designer who handles the complex problems holistically with a systemic perspective. Algorithms instead handle complexity through very simple tasks, which are iterated continuously.

3) Design Thinking Contribution's to Artificial Intelligence

If AI empowers a more sophisticated design process, the reverse can also happen (Verganti et al., 2020). Design Thinking (DT), following its keen interest to the managerial community, is found as a fundamental process to innovate models and digital application of disruptive technology (Liedtka, 2014; Cautela et al., 2019). Indeed, DT can ensure successful AI implementations (Advani, 2019) as it enable AI adoption process to be more effective, more human-centered, more creative and collaborative (Verganti et al., 2020).

In this study, following the lack of research on this aspect, we will demonstrate, in the light of examples of companies developing AI, how the DT process will contribute to making their outputs of AI applications more effective, more human-centered, more creative and collaborative.

- **More human-centered**

To ensure successful implementation of AI, organizations must first determine why and how to apply AI to specific problems in humanity (Advani, 2019). This starting point perfectly announces the crucial role of DT in AI.

As mentioned by Brenner et al. (2015), "*Design thinking is a profoundly human-centered methodology. There are human needs at the root of every innovation*". This DT principle becomes increasingly important while developing AI applications: this includes identifying, understanding the problem at a deeper level and assessing the current situation while make the consumer at the center of the operation.

For example, achieving people's centrality in the hospitality industry is extremely difficult because their customers are very diverse in terms of cultures, genders, backgrounds, travel plans, travel intentions, and budget. As an indicating of cultural complexity, the online travel agency Booking.com implements an intelligent chatbot that translates into 43 different languages.

In the example of the hospitality industry, both Booking.com and Airbnb use AI intensively for customized listening and aiding hosts in the decision-making regarding pricing. According to their website, Airbnb uses AI "to reduce the friction that is inherent to their platform, for everything from improving search, to preventing fraud, to helping hosts optimize pricing". However, Booking.com's innovation process is less driven by design, but, rather, by intense use of A/B testing" (Verganti et al., 2020).

This design approach made it possible for Airbnb to become a core node of its network easily, helping Airbnb to boost its reputation, enriching the user base due to the magnitude of the host. This ultimate focus of people: concentrating on each person would have been very difficult to accomplish without the process of DT (Verganti et al., 2020).

- **More effective: Tools and visualization**

Schindlholzer (2014) described a range of methods (visualization, ethnography, co-creation...) and tools (journey mapping, stakeholder Map, empathy map,) extend from guidelines to design workspaces useful used to build prototypes (Brennen et al., 2016).

The process of DT becomes handy especially with the previously mentioned variety of tools that makes the creation of AI more effective. According to Liedtka (2014), the first step in the need-identification, before the creation of AI applications, includes a variety of ethnographic research techniques, such as participant observation, job to be done, and journey mapping. The second stage of ideation includes sense-making tools (e.g., mind mapping and other forms of cluster analysis) and ideation tools to guide brainstorming and concept development. Prototyping and testing approaches to

support experimentation (assumption testing and field experiments) are part of the third phase of testing. Other tools, such as visualization and co creation, are used throughout the whole process as well.

In the previous example of the Airbnb company, as a housing search and reservation platform, employed the storyboard technique which helped them to create the full story of the interaction between consumers and their service, they dug into deep details including the traditional potential customers' information such as, gender, age, city and country, to their mood, how their day was, how many bags do they have, how do they fee exactly, and their goals for the journey.

- **More Creativity**

DT and AI function on different logics: DT solves problems and generates solutions through abductive reasoning, whereas AI leverages only deductive reasoning (how things are) and then inductive reasoning (by making hypotheses about how things might be). This contradiction in logics creates a complimentary effect. The creativity brought by the DT supports the creation of a more advanced and innovative AI applications (Verganti et al., 2020).

- **More collaboration**

To lead innovations in AI, the chiefs of executives will have to apply DT approach to develop collaboration among cross-functional teams (Advani, 2019).

The DT process also creates a harmful environment that challenges conflict and hierarchy, and encourages intelligent risk-taking (Advani, 2019). Liedtka (2014) stated that the essence of environmental ambiguity involves a kind of user's "generative engagement" in which "the difference between designers of AI applications and users has blurred, leading to the formation of a co-designer's community". This co-creation orientation offers a distinctly social focus and emphasis on collaboration.

The decision-making literature suggests that IT engineers should be-working in teams (preferably diverse multidisciplinary ones) to reduce reliance on self. By exposing decision makers to the viewpoints and inclinations of their colleagues, it allows them to differentiate their own perspectives from those of other decision-makers. Madjar et al. (2002) illustrate that interactions with others from diverse backgrounds ameliorate the creativity of individual responses which creates more innovative AI and reduces the percentage of errors.

The previously mentioned DT tools are employed in the co-creation process, these tools include visualization which captures individual ideas on post-it notes and whiteboards so they can be shared and created jointly. Co-creation welcomes others into the processes of both idea formation and testing. Structured sense making and brainstorming tools encourage team-based processes for drawing insights from ethnographic data to create a more effective AI application (Liedtka, 2014).

The startups were selected from the Tunisian platform STARTUP ACT (www.startupact.tn), a database containing a list of new companies operating in the digital world. The investigation was conducted on startups offering DT services through the use of AI; and reciprocal on startups offering AI products or services through the use of DT process.

1) Case Study 1: Med.tn

An appointment booking, medical director and consultation platform are provided in Tunisian medical context. Med.tn is an innovative Tunisian platform that allows users to find quickly and in real-time a doctor closest to his context and to make an appointment online for free. As a labeled startup since May 2019, Med.tn can offer hyper-personalized solutions to improve the health and well-being of the individual.

By referring to the main DT phases presented in the literature and identifying the AI solutions applicable to these DT phases, Med.tn startup demonstrate how the DT approach is currently transformed by the integration of this cutting-edge technology.

Developing empathy with users becomes an immediate, direct and reliable process, without intermediaries or personal interpretation. User understanding is becoming more and more intensive and can occur in a variety of real day-to-day situations, also promoting more objective and relevant framing of issues.

Med.tn allows users to put online personalized questions directly to physicians with confidentiality and immediately provides users with information on the most common symptoms of illness. The company is databases that turns data from sensors and transform it into rich insight and people's recommended behavior in real time.

Recommendations, oriented solutions to guide the references and the choices of the users on the basis of the information provided such as for example a specific treatment according to the symptoms or directly proposing drugs in immediate answers to the questions of the patients.

2) Case Study 2: Tunisian International Center for Digital Cultural Economy (TICDCE)

Augmented reality (AR) and virtual reality (VR) technologies are taking hold in the Tunisian cultural context. It is a Junior Network labeled start-up which was launched in October 2018 by TICDCE.

Tunisia Reborn is a gadget (microcomputer) with an AR application installed on it that allows visitors to archaeological sites to see the reconstructed ruins in 3D, as they were originally.

The Tunisia Reborn gadgets will be available for rent at the ticket offices of the targeted archaeological sites. Valuing cultural heritage, Junior Network has adopted the stages of the DT process.

Junior Network understands the situation of users, their motivations and challenges they may encounter by observing them and exchanging. The team interviewed two potential users to building persona.

To define the problem, the team gives a summary and definition of the major problem that the participants have identified. Some questions raised in this phase:

- How could we meet the expectations of our users?
- What could improve our products or services in light of these discoveries?

In order to generate more ideas, Junior Network has developed a brainstorming workshop to know how to package the solution and determine the Business model with which the startup can generate income to ensure the scalability and sustainability of the project (cf. appendix 1).

The company is in the process of technological study to choose the appropriate technologies.

For the tests, the participants have chosen the PDCA cycle (Plan-Do-Check-Act) as a reference. So, they plan to do an MVP (Minimum viable product) for the first iteration. This MVP was tested with different focus-groups to collect as much feedback as possible and check if they were able to meet the expectations and requirements of their users.

The schedule for the second iteration depends on the output of the first. The solution is therefore iterative and incremental. For each iteration, the increment will be inspired by the requirements and expectations of users and the needs of the market.

IV. DISCUSSION

The analysis made on the two case studies has produced some relevant insights, helpful to understand how AI and DT can benefit from each other.

The first case study demonstrated how the DT process is being transformed by AI. Particularly, the Med.tn case study highlights the specific contribution of AI applications to the empathy phase in medical domain described in the previous paragraphs.

Linking with previous research, empathizing stage looks to be the most transformed or covered by AI (Cautela et al., 2019). The selected startup belongs to one of the area's most welcoming to AI innovations.

This technology makes it possible to call on a variety of categories of information sources and databases to be of instant service to humanity. The user can reach favorable outcomes crowned with reliable and meaningful information in a faster and easier way.

The second example demonstrates how DT contributes to the innovation of an output of AI. The case study of Tunisia Reborn demonstrated the fluidity of the AR innovation process by applying the DT steps. This case study demonstrates how the DT process will contribute to making their outputs of AR applications more effective, more human-centered, more creative and collaborative. Moreover, Tunisia Reborn has adopted the iterative approach following inter-stage round trips in order to adjust and improve the final product associated to the predefined needs at the outset. DT makes it possible to overcome the challenges that organizations face during the development of AI applications (lack of efficiency, holistic approach, hierarchy, risk, gaps at strategy level.). It can make the implementation easier and

faster (Advani, 2019). When DT is deeply embedded in an organization's culture, it becomes easier to adapt to the changing market conditions (Advani, 2019).

V. CONCLUSION

AI and DT have much in common, but they can also greatly benefit from each other. DT can help to make AI applications and platforms more creative, faster and more flexible, by helping to accelerate learning processes in marketing management.

AI can give to DT impulses with the recent advancements of Information and Communication Technology (ICT), as long as it does not fall into the pitfalls of oversimplification of the foundations in social psychology and business management are not neglected in the innovation process.

This paper, flowing an interplay between the two concepts areas, mainly recognize similarities' points of AI solutions with DT principles as "human orientation and user centeredness", "innovation and creativity", "interdisciplinary collaboration", "solve problem and find solution" and "iteration and experimentation".

It is crucial to create a useful space for design thinking. (Advani, 2019) suggested that DT is an organizational phenomenon and should not restrict to specific department in a firm. Hence it is important to develop a culture within the organization to accommodate and implement DT at all functions and all employee levels (Advani, 2019; Lee et al., 2020).

DT, in order to make the solution more efficient, often follows an iterative process checking and correcting the results of each step. Therefore, good management, useful recruitment and regular audits are also important functions to successfully implement an AI application driven by DT.

To conclude, it is generally accepted that implementing AI applications is not an easy task. Several AI projects fail because they do not fully meet human needs, or do not reach their full potential for effectiveness. Some organizations with ideas in AI might not be able to achieve exactly what they thought. The final AI solution may not meet expectations and not deliver accurate results. Therefore, it is important for organizations to assess their capabilities and follow a process that reduces the risk of failure.

The DT approach is found to be extremely effective, which has been proven by academic research as well as by various applications across industries.

It's time for organizations planning cutting-edge AI innovations to learn from successful applications of DT. This is a promising approach that simplifies the implementation process and gives a clear picture of the progress, completion, efficiency and accuracy of a project (Advani, 2019).

According to Nelson the value of AI is not in the AI business models, but in the ability of companies to leverage them and these capabilities can be developed by following the DT approach.

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A complex management of road safety in Tunisia: Tension between alliances and operational conflicts between actors

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Abstract— Thinking about public intervention and more particularly its implementation naturally leads to an interest in the management system, to identify and formalise the relations between the different actors, analyze the role of institutions and understand the interventions of organizations. To do so, we used the MACTOR method. It is a medium for analysing alliances and potential conflicts between actors in a system. The results of the MACTOR analysis make it possible to question the scenarios of evolution and stability/instability between the different actors of a system. This method is supported by MACTOR software. Accordingly, according to the degree of influence and the degree of dependence of each actor, we have distinguished 4 types of actor : dominant players, intermediaries who are dominated or dependent, those who have little influence and are heavily influenced and autonomous actors are actors with little influence and little dependence. This approach makes it possible not only to grasp the complexity of the road safety system, but also to help identify avenues of intervention and reform consistent with the context of Tunisian action.

Keywords— road safety, institutional actors, alliance games, conflicts of interest, Tunisia

I. INTRODUCTION

The multiplicity of actors from different ministries and the private sector, as well as the cross-cutting nature of public road safety policy, undoubtedly require coordination for the purpose of order the interventions carried out and ensure the coherence of the strategy implemented [1]. And like other developing countries, Tunisia has implemented a wide range of road safety measures, but without significant progress being made. Indeed, from a management perspective, it is clear that road safety is a complex area to manage given the plurality of its stakeholders [2]. However, the terrorizing aspect of its record in Tunisia can be explained in part by an inadequate management system and the absence of an effective operational framework [3].

The institutional landscape of road safety in Tunisia seems to be weakened by several constraints: budgetary, structural, organizational, strategic, human, etc. Each institution

appropriates missions and attempts to act effectively on road safety. However, there is a problem of institutional sharing, exchange of accusations and recriminations, due to a lack of communication. There are, in fact, multiple actors, but an ambiguous definition of their roles and coupled with coordination and communication problems, which leads in some cases to uncoordinated and/or unsynchronized actions. This multiplicity of actors requires coordination and transversality in order to harmonize urban planning, development and transport. However, this is sometimes not validated. Poor institutional communication, particularly horizontal communication (between institutions), contributes to the increase in road accidents in Tunisia [4].

Based on this hypothesis, we conducted a survey of people representing 14 institutions involved in the road safety sector in Tunisia, using the semi-open interview technique. The interviewees hold local, regional and national positions of power in various sectors of activity (high level authorities "IHN", interior "MInt", health "MS", regional planning "MEHAT", higher education "MERS", insurance companies "CA". Associations "ASSO", municipalities "MUN", auto schools "AutoE", education "MED", mass media "Medias", justice "MJ" and transport "MT" and private freight transport company "STM"). Consequently, it would be advisable to highlight the evolution of strategic issues through the analysis of stakeholder games. To do this, we have chosen the Mactor method.

II. THEORETICAL CONTEXT AND METHODOLOGICAL CHOICES

The architecture of this study is based on the fundamental principles of the sociological analysis of organizations. These principles derive directly from the basic postulates of the strategic analysis of actors defined and put forward by Crozier and Friedberg in 1977 [5]. A theoretical synthesis of the "strategic analysis" developed by the authors, this book has become a reference in sociological literature as well as among management professionals. Based on numerous case studies, it studies the power relationships and strategies that actors

develop within organizations in order to understand the underlying logic and to delimit the zones of uncertainty - those interstices where interpersonal issues take precedence over the rationality of the system. Beyond the world of companies and administrations, it is to a more general reflection on the problems of collective action that this article invites us.

This is the following principle: road safety management in Tunisia (system) is based on the managerial latitudes and strategic objectives of the various stakeholders (actors). In addition, this methodology includes the positioning of the actors in relation to the strategic objectives, including their convergence or divergence, which conditions the success or failure of the road safety development strategies. Each actor operating in the sector has a margin of manoeuvre to implement its strategic game and a capacity to influence that is levelled at its degree of control. The various stakeholders do not have the same formal and informal resources. This imbalance leads to inequalities in the exercise of power [6]. The analysis of the players' game, the confrontation of their projects, the examination of their power relationships (constraints and means of action) are essential to highlight the evolution of strategic issues and to ask the key questions for the future (consequences of foreseeable conflicts). This is precisely the objective of the MACTOR method. It seeks to estimate the balance of power between actors and to study their convergences and divergences with regard to a certain number of issues and associated objectives [7]. From a methodological point of view, MACTOR comprises seven phases ranging from the construction of the "stakeholder strategies" table to the formulation of strategic orientations and fundamental questions for the future [8]. This method, supported by the MACTOR software, highlights the potential alliances and conflicts between road safety stakeholders in Tunisia.

Consequently, according to the degree of influence and the degree of dependence of each actor, we have distinguished 4 types of actors:

- The dominant actors, i.e. those who have a strong influence on the others without being strongly influenced themselves.
- The relay actors, those who are both strongly influential and strongly influenced.
- Dominant or dependent actors, those who have little influence and are strongly influenced.
- Autonomous actors are those with little influence and little dependence.

III. MAIN RESULTS

The main results from the MACTOR analysis are as follows:

A. Positioning of the actors on each of the objectives and identification of convergences and divergences

As a first step, we constructed the stakeholder cards, which is a square table of stakeholders/actors such that the diagonal contains the objectives of the stakeholder concerned and the

other boxes contain the means of action that each stakeholder has over the others to achieve its objectives.

Next, based on the survey of interviews, we classified the objectives according to five fundamental issues of road safety: road safety management, infrastructure and mobility, safe vehicles, human behaviour and tertiary safety (Table 1).

TABLE 1
 ROAD SAFETY ISSUES AND ASSOCIATED OBJECTIVES

Road safety issues	Objectives by actor
Road safety Management	<p>IHN 1: Create a lead road safety agency in the form of an interdepartmental body that could position road safety as a "public problem" to be addressed in an integrated approach.</p> <p>IHN 2: Decentralize authority and reflect real political will through the development of a well-defined strategy that is communicated to all stakeholders and levels of authority</p> <p>M.Int 2: Integrate BAACs to ensure comprehensive and more reliable national data production</p> <p>Mun 2: Implement local restrictive measures on heavy truck traffic in city centers.</p> <p>M.J 1: Rehabilitate the judge's margin of jurisprudence in the insurance code by revising the compensation scale for damages resulting from road accidents</p> <p>M.J 2: Recommend a bill to increase the minimum driving age and to include criminal liability for non-compliance with regulations.</p> <p>CA 2: To supervise the management of the National Road Safety and Guarantee Fund of road safety.</p> <p>MERS 1: Facilitate access to crash data for researchers and encourage them financially and logistically.</p>
Infrastructure and mobility	<p>MEHAT 2: Reconfigure urban spaces and their design to relieve congestion and reduce traffic accidents.</p> <p>MEHAT 1: Improve the supply of parking and variable message signs, and eliminate substandard speed bumps.</p> <p>M.T 2: Consider the safety needs of vulnerable road users in the design and management of road infrastructure.</p> <p>MUN 1: Improve the movement of pedestrians and people with reduced mobility by improving sidewalk clearance and roadway widening.</p>
Safe vehicles	<p>M.T 1: To develop a more efficient and attractive public transport system to minimize the use of individual transport and to fight against the ageing of the vehicle fleet through the technical control.</p> <p>C.A 1: Solve the problems of insurance for motorized two-wheelers, pushing towards the creation of an identification system for this type of vehicle.</p>
Human behavior	<p>M.Int 1: Automate the control-punishment system in order to reduce the direct intervention of the police officer on the road</p> <p>M.Edu 1: Formally include traffic education in the elementary school curriculum.</p> <p>AutoE 2: Adopt a personalized approach that will train the applicant on regulations for all modes of travel.</p> <p>AutoE 1: Standardize the national curriculum for traffic law training among all governorates.</p> <p>MS2: Integrate traffic prevention within hospitals by creating communication circles with patients.</p> <p>ASSo 1: Contribute to changing road behavior through awareness activities dedicated to road users and through road safety education.</p> <p>Media 1: Multiply education and awareness</p>

	messages and media coverage of road safety to correct road behavior. STM 1: Focus on vocational training for fleet drivers on road safety in order to reduce the costs of economic activity.
Tertiary security	M.S1: Promote cyber-communication between post-accident actors. M.J 3: Reduce the duration of the legal procedure of the accident and recommend the improvement of the quality of the PV.

Then, the first MDI matrix (input data) corresponds to the direct influence and dependence of one actor on another and is rated on a scale from 0 to 4:

- 4: actor i can question the existence of actor j,
- 3: actor i can question the accomplishment of actor j's missions
- 2: actor i may question the success of actor j's projects,
- 1: actor i can challenge the management processes of actor j in a limited way in time and space,
- 0: actor i has little influence on actor j.

MDI	IHN	M.INT	M.S	MEHA	M.ED	MERS	M.T	M.J	C.A	AutoE	MUN	ASSO	Medias	STM
IHN	0	3	3	3	3	3	3	3	3	3	3	3	3	3
M.INT	2	0	3	3	3	3	3	3	3	3	3	3	3	3
M.S	2	2	0	3	3	3	3	3	3	3	3	3	3	3
MEHAT	2	2	2	0	3	3	3	3	3	3	3	3	3	3
M.ED	2	1	1	0	0	0	0	0	0	0	0	0	0	0
MERS	2	1	2	2	0	0	2	0	0	0	0	0	0	0
M.T	2	3	3	3	3	3	0	1	0	0	0	0	0	0
M.J	3	2	2	3	3	3	1	0	0	0	0	0	0	0
C.A	1	3	1	0	0	0	2	2	3	0	0	0	0	0
AutoE	2	2	2	3	3	3	2	2	0	0	0	0	0	0
MUN	2	3	3	3	3	3	1	0	0	0	0	0	0	0
ASSO	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Medias	2	2	2	0	1	1	2	0	0	0	0	0	0	0
STM	2	1	1	1	0	0	0	0	0	0	0	0	0	0

Fig.1 Matrix of Direct Influences (MDI)

On the other hand, the matrix of valued positions Actor X Objective (2MAO) provides information on the actor's stance on each objective (pro, against, neutral or indifferent) and the hierarchy of its objectives. The sign indicates whether the actor is likely to reach objective or not.

- 0: Objective has a bleak outcome
- 1: Objective jeopardises the actor's operating procedures (management, etc...) / is vital for its operating procedures
- 2: Objective jeopardises the success of the actor's projects / is vital for the success of its projects
- 3: Objective jeopardises the accomplishment of the actor's mission / is indispensable for its missions
- 4: Objective jeopardises the actor's existence / is indispensable for its existence

2MAO	IHN	MINT1	M.S1	MEHAT1	M.ED1	MERS1	M.T1	M.J1	C.A1	AutoE1	MUN1	ASSO1	Medias1	STM1	IHN2	MINT2	M.S2	MEHAT2	M.T2	M.J2	C.A2	AutoE2	MUN2	ASSO2	Medias2	STM2
IHN	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
M.INT	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
M.S	1	1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MEHAT	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M.ED	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MERS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M.T	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M.J	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.A	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AutoE	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MUN	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ASSO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Medias	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0
STM	2	2	1	3	1	0	1	0	0	0	0	1	1	2	1	0	1	0	0	0	0	0	0	0	0	0

Fig.2 Valued position matrix

B. Evaluation of the actor's power relationships

MACTOR can develop the influence/dependency map from which 4 groups of actors are identified:

* Dominant actors : The Ministry of Public Works and the municipalities are actors with a strong influence on the others without being strongly influenced themselves. this can be explained by their strong impact on land use planning and road management. The media, referred to as the "fourth estate", are dominant because of their power to influence and the pressure they can exert on public opinion.

* The ministries of transport, justice, and the interior, as well as high-level institutions, have a strong influence, but they are also highly dependent. They have structuring powers in the area of road safety, particularly in terms of legislative strategy. Nevertheless, the success of their projects requires the strong involvement of other actors.

*The matrix shows that freight companies, insurance companies, driving schools and ministries of health and higher education have little influence, but a strong predisposition to be influenced. They are actors who find themselves in the fray of a very complex sector and demonstrate a combative attitude to succeed in their projects.

*Autonomous actors: The Ministry of Education and the associations are both low influence and low dependency actors. Their involvement, essentially limited to a proposal and awareness-raising role on road safety, gives them a great deal of autonomy in terms of decision making and action plans, but without having direct power over the other actors.

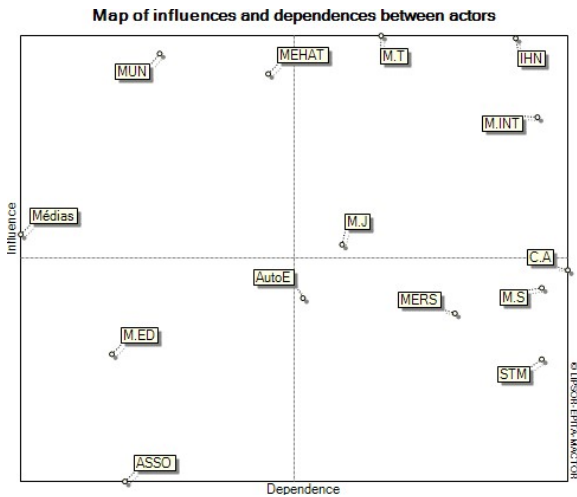


Fig. 3 Map of influences and dependences between actors

If the MEHAT and the M.T. have the same ambivalent position with all the actors, they are then ambivalent (Fig. 4).

On the one hand, they favor the accomplishment and success of an actor's projects on some objectives, but at the same time they question his success on others. The media have zero ambivalence because they are outside the panoply of convergences and divergences (information tool, position of neutrality with all the other actors).

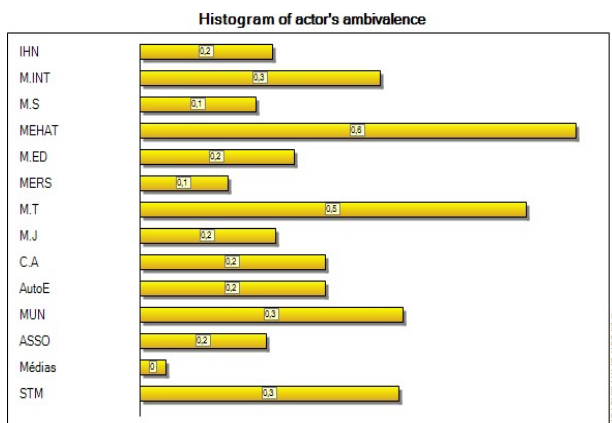


Fig.4 Histogram of actor's ambivalence

C. Integration of power relations in the analysis of convergences and divergences between actors

The map (Fig.5) identifies the objectives on which the actors take the same position (either for or against). This figure of the net distances between the objectives makes it possible to identify the objectives on which the actors are positioned in the same way. This map is used to isolate groups of objectives on which the actors are in strong convergence or divergence.

Note that the colours shown in the figure designate the issues of road safety management, infrastructure and mobility, safe vehicles, human behaviour and tertiary safety respectively. For example, the objectives that fall under the

heading of improving human behaviour bring the actors concerned together because the net distance between these objectives is the greatest. However, it seems that the management issue causes the actors to diverge widely, especially the legislation aspect, which creates repulsion and dispersion.

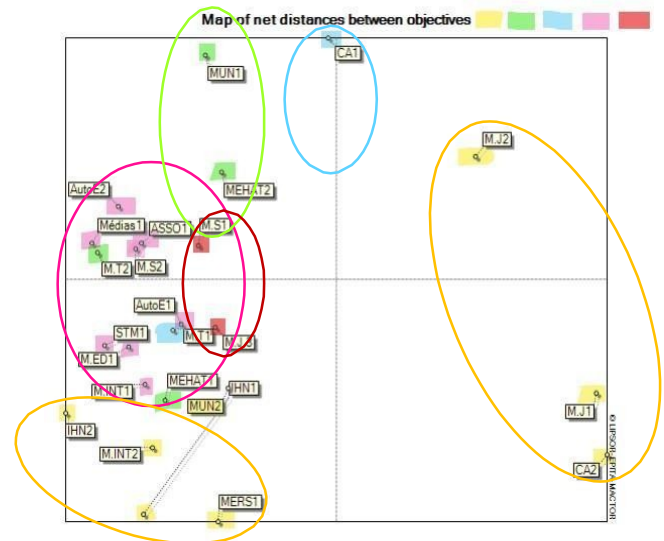


Fig.5 Map of net distances between objectives

On the other hand, The graph of net distances between actors is used to recognize potential alliances while taking into account divergences and convergences between actors according to Fig. 6, the MS, MInt and IHN actors show a strong complementary relationship (post-crash, databases). This complementarity is the subject of potential alliances, but, for example, the MEHAT and the MT (strongly ambivalent) present conflicting positions. Therefore, we can conclude that the more ambivalent the actor is, the more difficult it is to establish alliances with him.

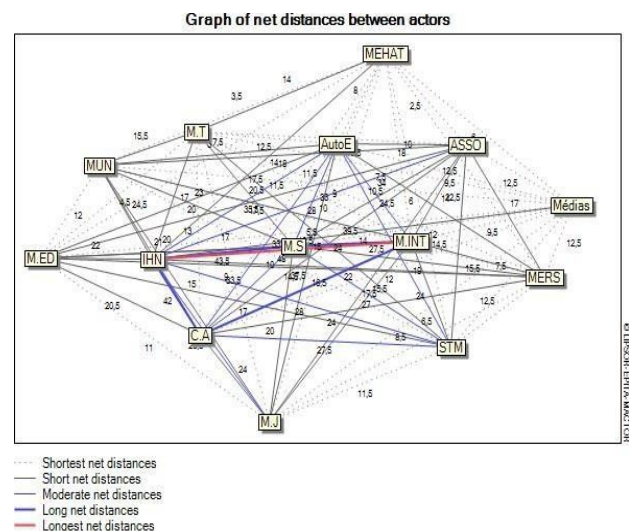


Fig. 6 Graph of net distances between actors

IV. KEY CONCLUSIONS AND RECOMMENDATIONS

Confronting the immense challenge of road safety in a way that solves the problem and does not exacerbate it is perhaps one of the greatest challenges facing the actors involved.

We reinforce the idea of the complexity of the mission of coordination among actors. This complexity already begins with the opposition of some actors to the unavoidable objectives of the project [9]. This can be explained by a weak mobilization of actors on common objectives and a strong opposition on objectives considered important for the implementation of an integrated strategy.

For this reason, it would be preferable not to try to ally oneself with strongly ambivalent actors like MEHAT and MT. In sum, there are problems of leadership and institutional management in the area of road safety because an integration strategy is absent in Tunisia and this is a big mistake. In addition, the lack of interministerial action that produces coordination and increases the costs of cooperation between actors.

This research work proposes a reflection on the convergences and divergences between the various actors of road safety in Tunisia. This reflection can be expressed in the form of operational recommendations.

A new system will make it possible to group all the professions related to road safety in a single organization, in the form of a leading agency, which will facilitate the implementation and realization of projects and a clear delineation of responsibilities. This would also allow the agency to strengthen the proximity between actors through its local and regional representations and to consolidate actions between the ministries concerned.

Moreover, the differences between MEHAT/MUN and MINT/MT can be corrected by placing the two actors under the supervision of a single national authority in charge of road safety. Indeed, inter-ministerial action contributes to the efficiency and effectiveness of public policies and partly shapes the policy management system. The political and managerial dimension of public road safety action is rarely mobilized, although the conditions for its implementation are crucial [10].

The position of municipalities, which are heavily involved but have no real decision-making power, requires a rethink of the place of road safety in local management processes. It is also necessary to rebalance the power forces by strengthening the prerogatives of the associations (representativeness) and the dominant actors (media).

It would also be wise to leave room for the market logic of private actors (CA, STM, and AutoE.) and to grant them ample sources of power, given their extensive involvement in the sector.

In addition, several management tools could be used to implement an effective strategic plan. For example, the RACI (Responsible Accountable Consulted Informed) responsibility matrix could help clarify the roles of each of the stakeholders in road safety. This tool provides an operational response to

visualize the distribution of roles at a glance. It is a relevant coordination and communication tool for complex projects such as road safety improvement where problems of overlap, ambiguity and redundancy of tasks are possible.

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Monetary Policy Communication and Transparency and Tunisian Bank Performance in Post-Revolution and Covid-19

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Abstract—One of the primary roles of central banks is to ensure financial stability, a role that is strengthened during times of crisis. Only an effective framework for monetary policy, which includes fundamental components like independence, transparency, and pertinent communication strategies, can help achieve this goal. The threat of bank instability does not exempt Tunisia because of the country's turbulent political environment since the Jasmine revolution, which has been exacerbated by the Coronavirus crisis. The literature documents a wide series of bank profitability determinants, but scarcity is noteworthy regarding the importance of central banks' institutional framework and its potential impact on bank performance. We purposely use a novel index of monetary policy framework (IAPOC) developed by [70] and argue that it contributes positively to Tunisian bank profitability and stability based on a sample of 23 banks over the period 2011-2020. The result is robust to the use of many measures of bank performance, to the use of sub-indices of IAPOC which encompasses independence and accountability (IA), policy and operational strategy (POLOPS), and communication (COMM). To strengthen our findings, we substitute the IAPOC index with a measure of central bank transparency of [30]. The panel regressions support again a positive effect on Tunisian bank profitability and stability.

Keywords— bank profitability, bank stability, IAPOC, central bank transparency, panel regressions

I. INTRODUCTION

Banks operate in a constantly shifting environment, they face therefore risks that jeopardize their stability. Financial stability can be described as a situation where the financial system, which includes financial intermediaries, markets, and market infrastructures, can withstand shocks and correct financial imbalances. As a result, the central bank has been tasked with creating a framework for monetary policy that is effective and coherent and depends on the disclosure of high-quality information to increase transparency. This has been the case since the 2008–2009 global financial crisis and the Basel III agreements strengthening these procedures.

Given the paucity of research on these topics, it is pertinent to ask empirically how much such a policy framework and transparency affect bank behavior. Most of the existing studies have emphasized the bank-specific and macroeconomic factors that affect performance. Our research adds to these studies, but we do so by supplementing the traditional determinants with a multidimensional factor that considers the institutional foundations of monetary policy; this factor is known as the IAPOC index and was recently created by [70]. This index is more comprehensive than other transparency or communication metrics suggested in the literature (e.g., [34]; [27]; [28]; [29]; [65]; [30]).¹ The transparency, coherence, and consistency axioms are combined into the IAPOC index. It is computed for a sample of 50 countries from 2007 to 2018.

In a very recent body of literature on bank risk-taking and performance, the significance of transparency is somewhat highlighted. The idea, as put forth by [17], refers to commercial bank finance transparency rather than transparency in central banking. This distinction sets our study apart from earlier works in the field.² For example, the Australian banking system should adopt communication strategies to ensure transparency and prevent fraud ([51]). Transparent business practices decrease the chances of loan fraud, as demonstrated by [6]. [8] contend that China's banking system's high level of transparency helps to cut down on non-performing loans, but also has a beneficial effect on bank stability ([7]). [26] found that bank transparency has no impact on credit risk in Tunisia. The same result is shared by [61] in India using the corporate transparency and disclosure index. [19] showed that when banks are more transparent, uninsured deposit flows respond better to returns. [63] argued that NPLs and return on assets decrease when Turkish savings

¹ For a review of these measures, we refer readers to [32].

² According to ([17], p. 129): “Bank transparency can be defined as the availability to outside stakeholders of relevant, reliable information about the periodic performance, financial position, business model, governance, and risks of banks.”

banks are more transparent. [66] found a positive relationship between the corporate transparency index and the stability of Gulf Cooperation Council (GCC) banks.

The Tunisian banking system is sensitive to the adverse effects of various global crises, so it is the target country of our study. Since the Jasmine Revolution, the economy has endured a dire political climate, culminating in the coronavirus crisis Covid19 and sending the nation back into recession. The Central Bank of Tunisia (CBT) mission is increasingly narrow and complex. The CBT must be more transparent and accountable to maintain public trust, protect independence and be more effective. In our empirical study, we show that the IPAOC index has a favorable impact on the stability and profitability of Tunisian banks. Our research is based on panel regressions and secondary data collection on 23 banks listed in the Tunis Stock Exchange over the period 2011-2020. The effect is robust to the use of several measures of bank performance. Replication of the results using the IAPOC sub-indices of Independence and Accountability (IA), Policy and Operational Strategy (POLOPS), and Communication (COMM) yields the same result, except for IA whose coefficient is positive, but statistically insignificant. Robustness check also includes the use of the central bank transparency metric of [30]. We again support the hypothesis that an upsurge in transparency boosts the health of the Tunisian banking system.

The outline of the paper is as follows. In Section 2, we review papers on the determinants of bank performance in Tunisia and the effect of central bank transparency. Data and methodology will be exposed in Section 3. We report and discuss the results in Section 4. Section 5 concludes with key policy implications.

II. LITERATURE REVIEW

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A. Determinants of bank performance in Tunisia

Literature concerning the potential factors of bank performance is well documented, but abundance makes reviewing all related papers unfeasible. Thus, our coverage will be studies conducted in the Tunisian context. Overall, we identify bank-specific, bank-industry, macroeconomic, and institutional factors of bank profitability or stability.

1) *The effect of credit and liquidity risks:* Risks are inherent to the core operations of the banking system. Empirical studies focus on two categories of risk. Credit risk refers to the default risk, meaning that a debtor will not be able to repay his or her debt on the agreed due date, thus causing a loss to the creditor counterparty (see [25]; [18]). The inability to repay the debt of the borrower is also akin to the situation of the financial market. The risk-reward trade-off indicates that the potential return increases as the risk increases. This implies that individuals associate low levels of uncertainty with low potential returns and high levels of

uncertainty or risk with high potential returns. We find such a positive effect on bank profitability in [11], and [35] though insignificant, and in [47], [53] and [75]. Others claim that an upswing in credit risk leads to better bank performance (e.g., [5]; [60]; [10]; [37]; [36]) or only when it exceeds a certain threshold (see [31]). Credit risk might have an ambiguous effect on the bank's performance ([43]). Liquidity risk arises when the bank is unable to meet its commitments with its available or mobilized current assets. Delay of the obligation to repay creditors and or the asymmetry of liquidity between its liabilities may put the bank in a situation of illiquidity. This vulnerability to liquidity risk poses a threat to the entire financial system because liquidity risk is an inherent systemic risk. The harmful effect of liquidity risk on bank profitability is underlined in studies like [10], [37], [35], [75], [57]. Some authors attempt the interaction between both risks in their analysis. [74], for example, argues that credit risk is detrimental to Tunisian bank profitability when the liquidity risk is set at higher levels.

2) *The effects of capital adequacy ratio, operating efficiency, and diversification:* Capital adequacy ratios have been recognized to assess capital adequacy efficiently and should reflect a bank's overall safety and health. It is generally accepted that well-developed banks have lower expected costs of financial distress ([1]). This benefit is portrayed by the significantly high profitability of the Tunisian banks (e.g., [35]; [53], [57]). Operational efficiency is another recognized bank-specific determinant. It provides financial institutions the flexibility to explore and test new market products and technologies, reward shareholders, and offer a range of services to customers at competitive prices. Banks with lower efficiency costs have mild chances in the market and become vulnerable to threats during a financial crisis ([77]). Operating costs lead definitely to lower bank performance in Tunisia according to [60], [10], [47], [36], [53], [75]. A booming credit market has allowed banks to partially offset this surge with record levels of lending. But to really boost their revenues, banks are focusing on diversification. This allows banks to better leverage their large customer portfolios with frequent contacts and trusted third-party images. Studies conducted by [10], [36], and [2] highlight the merits of bank diversification in the Tunisian context.

3) *The effects of size, ownership, and concentration:* Bank-industry variables play a prominent role in explaining bank profitability and stability measures in Tunisia. However, the existence or not of an effect as well as the associated sign are not unanimous. The introduction of size into estimates is often justified by the question of the existence or otherwise of economies of scale ([42]). Likewise, the profitability of banks depends on the quality of the financial structures of the country in which the banking institutions operate ([23]). The public or private nature of credit institutions' assets and the status of the bank are important qualitative factors of bank profitability. Whether the bank is private or public, the effect has been raised empirically in several studies (e.g., [13]; [49]; [3]; [35]; [57]; [75]). As regards banking concentration and the

size of the banking sector, their estimated impact on the profitability of bank assets is generally positive, as empirically confirmed by economic theory ([49]; [78]; [62]; [9]). The financing of the economy by the banking sector reflects the capacity of the system to meet the needs of economic agents. The size of the sector should then benefit the different actors ([24]; [48]). [12] emphasize the existence of a non-linear relationship between performance measured by return on assets and size. They argue that size negatively affects Tunisian bank profitability beyond a certain level. Similarly, concentration strategies and their development are traditionally justified by the achievement of economies of scale. The introduction of this variable has empirically demonstrated a positive association with the return on assets (e.g., [60]; [79]; [37]; [36]).

4) *Macroeconomic effects:* The functioning of banks depends on external factors. The two key documented factors are GDP and inflation. Particularly, we monitor the evolution of the consensus on the impact of GDP on bank profitability. National wealth benefits all economic activities in the country has a positive impact on the development of the banking sector, and will encourage banks to innovate in their management techniques ([42]). Several empirical studies ([60]; [35]; [75]; [57]) show a positive impact of GDP on bank profitability. In effect, the decline in GDP reflects a recession, which causes credit quality to deteriorate, leading to bank losses and reducing bank profits. However, the statistical significance of that variable is never guaranteed. Inflation affects the banking sector through the bank lending channel. [22] figure out that higher inflation should have a positive impact on bank profitability. [57] and [75] confirm the positive relationship between inflation and bank profitability measures, but the effect is insignificant. [36] argue that inflation improves significantly the return on assets. [5], [37], and [47], however, have a contradictory view. Aside from the impact of inflation on banks' interest rate risk, higher prices can certainly be seen as a driver of macroeconomic instability. This fact explains why inflationary pressures might decrease bank returns. Indeed, [3] find that inflation has a negative contribution to the bank's net interest margins in Tunisia.

5) *Institutional effects:* While the aforementioned factors of bank performance are extensively studied by researchers, the role of the institutional environment in banking is somewhat underestimated. Good institutional quality in terms of political stability, anti-corruption, and the rule of law can reduce adverse selection and moral hazard for borrowers, and improve lending conditions and loan repayments, which in turn affect bank performance ([14]). [16] makes an innovative contribution in this context by supplementing the standard determinants with the corruption index. It is widely admitted that corruption is detrimental to economic growth ([44]). Corruption, one of the main drivers of the Tunisian revolution, remains high and is fueled by political instability. Particularly, [16] underlines the positive effect of corruption on return on assets. The effect is indirect and mediated by loan quality, management efficiency, liquidity, and bank size. It is, however, hard to rely on such a

result which is drawn from a small sample (ten Tunisian banks) and is not robust to the use of other measures on bank profitability such as return on equity and net interest margin.

B. *The role of central bank transparency and monetary communication*

There is a growing body of literature on the effect of central bank transparency and communication strategies. Much of the related empirical literature consider inflation as the dependent variable. The reasoning is quite plausible. Clearer, more relevant, and timely disclosure of information about central bank practices improves price stability ([34]; [27]; [28]; [29]; [21]; [80]; [20]; [33]; [67]; [45]; [59]; [52]). In addition to linear relationships, some authors argue that central bank transparency is useful for reducing the persistence of inflation only when it exceeds a certain threshold, implying a non-linear relationship ([72]; [68]). New steps are being taken to link equity returns to central bank transparency. In this gap, we find the research of [54]. Based on a panel of 40 countries, the authors argue that greater transparency inevitably reduces stock market volatility, implying greater financial stability. [39] support the last observation by examining a direct link between the monetary and macroprudential transparency indices of non-performing loans and the occurrence of a crisis. Central bank transparency plays an important role in the mechanism by which monetary policy is communicated through interest rate channels in emerging markets ([55]). [56] show that central bank transparency moderates the relationship between interest rate spreads and emerging market equity returns. According to [73], exchange rate fluctuations are increasing in developed countries with a high degree of transparency. In the same context, [81] find less volatile exchange rates in countries with a high level of central bank transparency. Increasing monetary policy transparency pays off when targeting disagreements between economic actors for interest rate forecasting ([40]; [64]). A recent study by [41] demonstrates a positive impact of central bank transparency on foreign equity portfolio inflows, and this effect is amplified by a healthy institutional environment. The focus on the impact of central bank transparency on the banking system is very recent. [4] show that more transparent central banks can incentivize banks to engage in risky activities. [76] claim that the effect of central bank transparency on systemic risk depends on the level of economic development. In any case, the effect is always nonlinear.

III. MATERIAL AND METHOD

A. *Data*

We collect data from the annual reports of 23 onshore Tunisian banks from the Tunisian Professional Association of Banks and Financial Institutions (TPABFI) (<https://www.apbt.org.tn/rappports-annuels/>). Other variables are retrieved from the World Integrated Trade Solution (WITS) and the Global Financial Development Database (GFDD) of the World Bank. The coverage of data is from 2011 to 2020.

A total of 5 measures of bank performance have been constructed and 24 potential determinants have been compiled. We only keep those that pass the multicollinearity issue. Table I summarizes the final list of variables used in this study (To save space, we did not report the correlation matrix, but available upon request).

TABLE I
 VARIABLES, DEFINITIONS, AND SOURCES

Bank performance measures				
Profitability	ROA	Return on assets	Net profit/Total assets	Annual reports of TPABFI
	ROE	Return on equity	Net profit/Total equity	Annual reports of TPABFI
Stability	RAROA	Risk-adjusted return on assets	ROA/SD(ROA)	Calculations
	RAROE	Risk-adjusted return on equity	ROE/SD(ROE)	Calculations
	Z-Score	Bank Z-score	(ROA+ROE)/SD(ROA)	Calculations
Bank-specific factors				
RCRED		Risk of credit	Total credit/Total assets	Annual reports of TPABFI
RLEQ		Risk of liquidity	Total credit/Total deposits	Annual reports of TPABFI
DIV		Diversification	Fee and commission income/Gross revenues	Annual reports of TPABFI
EFF		Operating efficiency	Operating expenses/Net banking income	Annual reports of TPABFI
CAPAD		Capital adequacy ratio	Total equity/Total assets	Annual reports of TPABFI
Bank-industry factors				
OWN		Ownership	Dummy equals 1 if a bank is public and 0 if private	Central Bank of Tunisia
HHICONC		HHI index of concentration	HHI index of concentration	WITS
SBS		Size Bank System	Bank assets/GDP	World Bank, GFDD
Monetary policy communication and central bank transparency				
IAPOC		Independence and accountability, policy and operational strategy, and communication index	A multidimensional index consisting of three pillars according to ([70], p.4): “(i) Independence and Accountability, which provides the foundations of monetary policy; (ii) Policy and Operational Strategy, which guides adjustments to the policy stance given the objectives, as well as adjustments to the policy instruments to implement the policy stance; and (iii) Communications, which convey decisions about the policy stance and rationale to the public.” It is calculated based on a total of 225 criteria. Data for 2019 and 2020 are interpolated.	[70]
CBT		Central bank transparency index	A multidimensional index covering 15 aspects of five aspects (policy, political, operational, economic, and procedural) encompassed in [34]. The measure assesses monetary policy transparency.	[30]

Descriptive statistics of all variables are presented in Table II. All profitability and stability measures range between negative and positive values. The variables ZSCORE, RLEQ, IAPOC, and the sub-indices of IAPOC have a high standard deviation, meaning that they are highly dispersed around the mean. Low standard deviations are associated with ROA, RCRED, DIV, and HHICONC. Those variables are clustered around the mean.

TABLE II
 DESCRIPTIVE STATISTICS

VARIABLES	N	Mean	S.D.	Min	Max
ROA	223	-0.0113	0.0844	-0.474	0.0726
ROE	223	0.0691	0.437	-4.505	3.127
RAROA	223	1.321	2.424	-3.462	8.342
RAROE	223	1.972	2.898	-3.240	11.69
ZSCORE	223	17.75	31.73	-173.4	130.1
RCRED	223	0.799	0.0902	0.562	0.974
RLEQ	223	4.721	14.23	0.166	119.1
CAPAD	223	-0.0401	0.756	-4.253	0.636
EFF	223	0.596	1.464	-8.566	16.25
DIV	223	0.223	0.0877	0.0259	0.544
SBS	230	86.90	5.287	80.19	96.09
OWN	230	0.435	0.497	0	1
HHICONC	207	0.146	0.00917	0.131	0.157
IAPOC	228	120.3	14.00	102.7	136.4
IA	228	114.2	11.54	103.0	195.9
POLOPS	228	155.4	40.21	102.0	196.4
COMM	230	119.9	15.50	102.0	139.3
CBT	230	7.050	0.473	6.500	7.500

Note: ROA: Return on assets, ROE: Return on equity, RAROA, Risk-adjusted ROA, RAROE: Risk-adjusted ROE, ZSCORE: The sum of ROA and ROE divided by the standard deviation of ROA, RCRED: Credit risk, RLEQ: Liquidity risk, CAPAD: Capital adequacy ratio, EFF: Management efficiency, DIV: Diversification, SBS: Size Bank system, OW: Ownership dummy, HHICONC: HHI concentration, IAPOC: IAPOC index, IA: Independence and accountability, POLOPS: Policy and operational strategy, COMM: Communications, CBT: Central bank transparency index.

There is no specific dataset of the IPAOC index for Tunisia but since it is an emerging country, we depict compiled values related to emerging economies. Fig. 1 shows an upward trend of the IAPOC index during the period of investigation. The graph is marked by two periods in which the IAPOC index leveled off (2011-2012 and 2013-2015) before rising dramatically in 2016. It continues to grow steadily afterward. By examining each pillar of the IPAOC index, we find that the utmost change is made in improving policy and operational strategy. However, [70] state that there are still some challenges facing emerging countries (EM) in mapping their policy objectives into numerical targets still persist, with revisions being made frequently without a comprehensive review. Notably, EMs stand to benefit from enhancing consistency between the tools used in practice and those declared ex-ante. Additionally, the joint functioning of these tools and instruments is necessary in order to effectively implement policy.

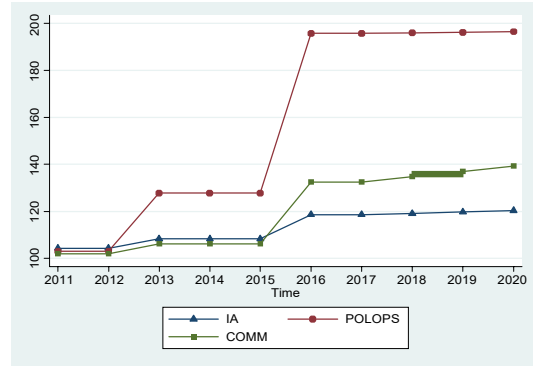
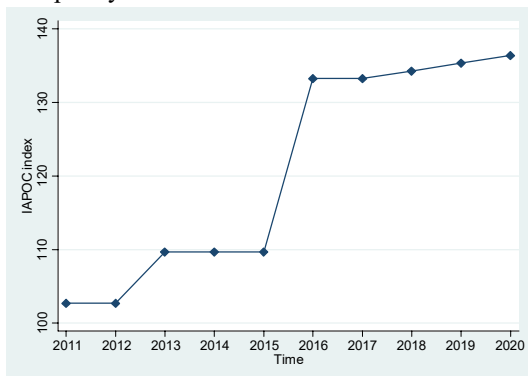


Fig.1 The evolution of the IAPOC index and its sub-indices

Note: IA: Independence and accountability, POLOPS: Policy and operational strategy, COMM: Communications.

B. Econometric specification

We employ a standard static panel regression to explain Tunisian bank performance relative to the IAPOC index, as well as a set of control variables.

$$y_{it} = \alpha_i + \theta IAPOC_{it} + \beta' X_{it} + \varepsilon_{it}, i = 1, 2, \dots, N \quad t = 1, 2, \dots, T \quad (1)$$

Where y is the dependent variable, IAPOC is the variable of interest, X is a vector of the explanatory variables, α_i stands for the individual effects, and ε_{it} is the idiosyncratic error term.

When estimating Eq. (1), issues such as serial correlation, heteroscedasticity, and cross-sectional dependence are warranted. Pooled, fixed effects (FE), and random effects (RE) models with clustered standard errors address the two first issues. Choosing the appropriate estimator requires the likelihood ratio test (LR) in the first stage. If LR is statistically significant at the 5% level, the random effects model should be conducted. We then apply the Shaffer and Stillman test to see if the fixed effect model is preferred over the random effects one.

However, ignoring cross-sectional dependence (CD) in our empirical framework can lead to biased estimates. In this case, we apply the Driscoll and Kraay estimator. To do this, we carry out the CD test of [58]. Here again, the choice between fixed effects models and random effects models requires the Hausman test developed by [38].³ We performed all estimations with Stata11.2 software.

IV. RESULTS AND DISCUSSION

The IAPOC index is the variable of interest in our initial panel regressions, which are presented in Table 3. This table clearly shows that the latter enters Eq. (1) in a positive and significant manner. Therefore, banks experience higher profits

³ As far as we know, there is no test that allows for a comparison between pooled Driscoll and Kraay and Driscoll and Kraay with fixed effects. So, we report both of them.

and greater stability when central banks enhance their monetary policy framework. Meanwhile, some bank-specific and bank-industry performance factors have a significant impact on the profitability and stability of banks. These include the ownership dummy (OWN), the size bank system (SBS), the capital adequacy ratio (CAPAD), and management efficiency (EFF). A closer look at Table III reveals that the diversification variable (DIV) exhibits heterogeneous behavior. Although the associated coefficient of the share of fees and commission is negative and statistically significant for ROA, it does not appear to have an impact on the other indicators of bank profitability and stability.

Unexpectedly, neither credit risk nor liquidity risk has an impact on the performance of the Tunisian bank. It is important to note that we excluded macroeconomic variables like the inflation rate from our analysis of bank performance. The argument is plausible. The correlation between the IAPOC index and inflation is strong (0.58, $p=0.000$). Results that include GDP do not consistently show a significant impact on the dependent variables (not reported to save space). The effect of other regressors was unaffected by the variable's exclusion.

We included a dummy that reflects the Covid19 crisis since it marked the end of the investigation period. Our findings disprove the existence of any statistically significant effect of that variable on the bank performance (not reported to save space).

The statistical results are explained in this section, but we need to go beyond inferences and offer explanations from the economic view.

- **The effect of the IAPOC index:**

The IAPOC index, by conveying transparency, coherence, and consistency of monetary policy framework leads undoubtedly to a healthier banking system. This implies that it is important to maintain and preserve the aspects of central banking related to monetary policy communication that proved to be robust, especially in crisis times and that will remain crucial to the future stability and prosperity of the world economy ([15]). A clear and relevant monetary policy framework can be used to support financial stability. Banks are therefore motivated to seek out more profitable assets after apprehending the systemic risks. Since the IAPOC index is made up of three pillars, we have tried to examine the specific aspects that influence the performance of most Tunisian banks. Thus, we regress the bank profitability and stability measures on the Independence and Accountability (IA) sub-index, Operational and Policy Strategy (POLOPS) sub-index, and Communications (COMM) sub-index, while controlling for the same set of other determinants (see Tables A1-A3 in Appendix). We believe that the independence and accountability sub-index has no impact on the bank's performance, but the other pillars have a positive and statistically significant impact on the bank's profitability and stability. Communication with the public and guidance on policy tools and positions are therefore very important. To further test the robustness of our results, we replace the

IAPOC index with the CBT index of [30]. Again, more transparent disclosure of information about central banks' monetary policies and practices leads to a healthier banking system, and Tunisian banks record better profits (see Table A4 in Appendix).

- **The effect of risk and liquidity risk:**

The increase in credit risk does not seem to have affected banks' performance. We share the same views as [11], [5], and [53]. As for the liquidity risk, we find the same result as [31] but contradicts most of the existing studies. In such a case, one could think of the existence of a nonlinear relationship. Therefore, we reproduce our results by including the squared terms of the two risks. Again, the nonlinear relationship is not statically significant for credit risk (result not reported to save space). There is, however, a U-shaped relationship between liquidity risk and ROA, meaning that increased liquidity increases return beyond a certain threshold. This result is statistically thin (the variable and the squared variable are significant at the 10% level), and therefore cannot be taken into account economically.

The results should be interpreted with caution. Panel regressions reject an immediate effect of the two risks. There are reasons to believe that the extent of the effects could emerge beyond a certain period of time. For example, a recent study by [69] shows that credit risk leads to instability of Tunisian banks in the long run, using a panel cointegration technique. Part of our result could be attributed to the measure used. We have applied a credit growth indicator, while the risk is more reflected in non-performing loans.⁴ Insufficient related information prevents us from using this indicator.

- **The effect of capital adequacy ratio:**

An increasing ratio of capital adequacy generates higher profitability and stability. The result implies a reduced cost of financial distress, which may rise expected profits.

- **The effect of management efficiency:**

The negative impact of the operating costs ratio on Tunisian bank performance appeals to the banks to reduce them in order to be more efficient and globally competitive. If we compare, the degree of management efficiency with developed countries, we grasp a nonnegligible gap.

- **The effect of diversification:**

We find a positive and statistically significant impact of diversification on bank performance portrayed by the negative sign on the measure of fees and commission as a share of gross revenues. The positive impact implies that despite the economic slowdown of the Tunisian economy exacerbated by political instability since the Arab Spring and the pandemic crisis, this downturn has not prevented banks from diversifying their portfolios and engaging in new investments and innovations, thereby increasing their returns. However,

⁴ That measure is employed in several studies such as [35], [36], [43], [11].

this impact is limited to the return on assets (ROA) as a dependent variable. The result is in consonance with [50] for the case of South Asian countries.

- **The effect of the size bank system:**

If bank assets to GDP rise, Tunisian bank profitability and stability measures decrease. The result is in line with the views of [22] and corroborates the finding by [3].

- **The effect of the HHI concentration index:**

The Herfindahl-Hirschman Index (HHI) is a common measure of market concentration and is used to determine market competitiveness is included only in the RAROE specification as it improves the result of some other coefficients, but its exclusion doesn't affect the magnitude and the statistical significance of the variable of interest, namely the IAPOC index. The HHI concentration measure itself doesn't affect the risk-adjusted return on equity (RAROE). This finding is not consistent with the theoretical view ([48]; [62]; [9]).

- **The effect of ownership:**

The associated coefficient with the ownership dummy is negative and statistically significant. The result reveals that privately owned banks are more profitable and stable and the publicly owned banks. This result is in accordance with many studies (e.g., [47]).

V. CONCLUSIONS

The global liquidity of the banking system has tightened significantly over the past few years, with average liquidity factors decreasing by 2040 MDT. With the advent of the Covid19, the banking system's weaknesses have only accumulated. These vulnerabilities are primarily concentrated in the size of non-performing loans, low bank profitability, and a lack of compliance with important banking supervision and stability standards. Without an institutionalized safety mechanism, the banking sector remains very vulnerable to future shocks ([46]).

While presenting the latest empirical evidence, our article explores previously underexploited research perspectives, such as institutional frameworks and central bank practices, to help address political and economic instability and its repercussions on the banking system. It analyzes the behavior of a sample of Tunisian banks from 2011 to 2020. To this end, extending this sample to all 23 onshore banks operating in Tunisia was highly desirable. This extension provides a clearer picture of the interaction between banking policy and global economic policy, and its relationship to the developments observed in Tunisia. Our contribution is enhanced by the use of the IAPOC index that remains unused. Compared to other studies with respect to the research objective which is different from ours, we provide sufficiently robust conclusions regarding the importance of enhancing transparency and communication of monetary policy by the

Central Bank. Our empirical analysis can be extended to analyze the effect of the IAPOC index on the profitability and the stability of the banks in the Middle East and North Africa (MENA) region. A comparative study between conventional banks and Islamic banks is recommended.⁵ We note further that the Covid19 crisis is associated with financial digitalization opportunities that can be fruitful to the Tunisian bank's performance. This should be left for future examination.

⁵ Distinguishing between conventional and Islamic banks in the Tunisian context is meaningless because there are two Islamic banks only.

TABLE III
 EFFECT OF THE IAPOC INDEX ON THE TUNISIAN BANK PROFITABILITY AND STABILITY

Variables	ROA		ROE		RAROA		RAROE	ZSCORE
	Pooled Driscoll and Kraay	Driscoll and Kraay with FE	Pooled Driscoll and Kraay	Driscoll and Kraay with FE	Newey	Driscoll and Kraay with FE	Within	Within
IAPOC	0.0004*** (5.946)	0.0003*** (4.368)	0.0035** (2.502)	0.0021* (2.148)	0.0284* (1.931)	0.0271*** (5.051)	0.0237*** (3.144)	0.2400** (2.102)
RCRED	0.0056 (0.339)	-0.0099 (-0.506)	-0.3707 (-1.466)	0.0178 (0.080)	-2.1020 (-0.966)	-2.3041 (-1.580)	-1.9500 (-1.116)	-15.7519 (-0.630)
RLEQ	-0.0003 (-1.525)	-0.0001 (-0.947)	0.0004 (0.845)	0.0008 (0.421)	-0.0136 (-1.170)	0.0102** (2.522)	0.0130** (2.390)	0.0997** (2.098)
CAPAD	0.1078*** (32.765)	0.1032*** (14.753)	0.1412* (2.096)	-0.4755*** (-4.877)	1.0446*** (7.808)	0.8037*** (3.747)	-1.0264** (-2.626)	- (-5.541)
EFF	-0.0039** (-2.430)	-0.0045*** (-6.353)	-0.2061** (-2.397)	-0.2919*** (-15.601)	-0.2497*** (-3.496)	-0.2296*** (-5.842)	- (-4.507)	- (-15.984)
DIV	0.0739*** (4.758)	-0.0105 (-1.090)	0.3995 (0.920)	-0.5277 (-1.741)	-1.0009 (-0.411)	-0.5783 (-0.365)	-1.4806 (-0.695)	-31.2961 (-1.024)
SBS	-0.0005*** (-3.925)	-0.0003*** (-3.547)	-0.0011 (-0.324)	0.0010 (0.404)	-0.0203 (-0.865)	-0.0127 (-1.114)	-0.0033 (-0.283)	-0.1238 (-0.542)
OWN	-0.0139*** (-5.028)	-0.0325*** (-3.589)	-0.1107** (-2.844)	0.3647* (2.111)	-2.4669*** (-5.899)	-1.3267*** (-6.871)	0.0180 (0.022)	6.4032 (0.357)
HHCONC							-1.5868 (-0.224)	
_cons	-0.0279* (-2.250)	0.0047 (0.221)	0.1241 (0.551)	-0.1774 (-0.428)	2.9554 (1.003)	1.8729 (0.893)	2.0127 (1.106)	22.1430 (0.650)
N°observations	221	221	221	221	221	221	199	221
Breusch and Pagan LM (p-value)	--	--	--	--	--	--	0.000	0.000
Schaffer and Stillman overid (p-value)	--	--	--	--	--	--	0.010	0.000
Serial correlation at the first order	Yes	Yes	No	No	Yes	Yes	No	No
Cross-section dependence	Yes	Yes	Yes	Yes	No	Yes	No	No
Hausman test (p-value)	--	0.000	--	0.000	--	0.000	--	--

Note: *t* statistics in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

APPENDIX

Tables A.1-A.4 are available upon request from the author.

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