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Digitally Enabled Decission Making in Big Crop Farms: Inspiration for a Balanced Decision Making Metaphorical Model

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Abstract. *This paper analysis decision making support systems in the big crops farms and proposes a metaphoric model to illustrate the interdependence of resources usage. The proposed metaphoric model is drawn considering that six types of resources (time, financial, people, knowledge, technology, relational capital) are spent to achieve an objective and puts forward a graphical representation, a hexagonal pyramid to illustrate the interdependence among these six types of resources (the polygon of resources) and the quality of the financial outcome (the height of the pyramid). Examples of digital decision support systems used in big crop farms were used to explain the model's functioning. A particularity of the model consists in the adding of a second mirrored pyramid (resting on the same base) with its height representing the assessment of the environmental impact as a proxy for ESG results. Consequently, the evolved model proposed by the paper, dubbed as The Value Creation Diamond, provides a good springboard in visualizing and assessing the balance between the scaled heights of the two adjoined pyramids (Financial height vs ESG height). The model is deemed to be a useful tool for practitioners as well as educators in their quest to facilitate the wider use of balanced decision-making model considering the resources and outputs in the realm of sustainable development.*
Further research will be instrumental to validate the possibility to use this model for other types of farms, firms and organizations.

Keywords: Value Creation, Decision Making Support Systems, Agriculture 4.0, Metaphorical Thinking

Introduction

Decision making is the essence of the management activity, it implies the thinking process of generating alternatives as well as the thinking associated with the choice making among multiple alternatives on how to solve problems (Bratianu et al., 2020b; Drucker, 1974). In the context of a firm its aim is to create value (Kraaijenbrink & Spender, 2011; Yar Hamidi, 2019).

An efficient value creation in the agricultural realm and its basic constituent unit, the farm, is highly desirable for both economic reasons (firm's viability and development) as well as food safety considerations (societal impact). The agricultural value creation went through historical progresses from the labor-intensive Agriculture 1.0 of the early 20th century through the "Green Revolution" of the 1950s (Agriculture 2.0) followed by the rise of precision agriculture in the mid-1990s (Agriculture 3.0) up to today's interconnected Agriculture 4.0 that leverages the latest innovations in sensor technology, digital image processing as well as data analysis and visualization (Zambon et al., 2019). These innovations made possible the rise of the digital agriculture allowing farmers to do a better management of farms in general and the management of the arable land and water resources by means of enhanced precision agriculture. Agriculture 5.0 will be about robotics and advanced artificial intelligence opening the road to farming through unmanned operations and autonomous decision making (CEMA, 2017).

Value creation in farms through Agriculture 4.0 is perceived to be more complicated to deliver than in the case of Industry 4.0 firms because value creating mechanisms in agriculture

DOI: 10.2478/picbe-2023-0111

are exposed to stochastic events (weather dependency) a lower degree of labor division and specialization than in industrial organizations, the relatively more frequent heuristics in the management process, as well as a mobility of the production facility (Braun et al., 2018; Zambon et al., 2019). The general expectation is that Agriculture 4.0 will help enhance food security, solve many value chain efficiencies, improve animal welfare, and significantly reduce environmental impact through reduced usage of chemicals. (Abbasi et al., 2022 ; Latino et al ., 2021; Dayioglu &Turker, 2021; Saiz-Rubio & Rovira-Mas, 2020; Klerkx et al., 2019 ; Trendov et al., 2019)

Profesional agriculture in the big crops farms in Romania is done in farms that are overwhelmingly family firms which most often built their scale through the family's joint exploitation of owned and rented arable land and rather rarely though cooperatives (Dumitru et al., 2022). The relative recency of the creation of these farms makes it also very frequent that the founding figure would still be involved in the operation of the farm nowadays aged 55+ or even 60+ (Rovný, 2016). The new generation of professional farmers is coming primarily from the inheritors as well as hired specialists.

This paper will focus on reviewing the way digital decision support systems improve decision making in big crop farms and will formulate a metaphorical model that could be used in other types of farms and firms in general.

Literature review

Resources

"Time, quality, money, pick any two" is an adagio often used by practitioners in the day-to-day effort to manage and implement multiple initiatives in companies as well as in public and non-governmental organizations under the umbrella of broad organizational objectives.

The project management theory of triple constraints, time vs. cost vs. scope influences quality, is making it explicit (Van Wyngaard et al., 2012). The theory states that the successful project management is about balancing the time, the costs, or the scope of the project to deliver at the set/desired quality. This establishes an "iron clad" trade-off type of thinking that could also be expressed as: specific costs and time are needed to deliver the desired quality (i.e., resultant value) for a well-defined scope.

The value innovation concept (Kim &Mauborgne, 2015, p. 13-17) showed that low cost and differentiation (often a proxy for quality) can be achieved simultaneously. The new better perceived value obtained with a lower consumption of resources is therefore possible and the case of Circ du Soleil is considered illustrative (Kim & Mauborgne, 2015, p. 3-4). This is not contradicting the triple constraint theory; it rather builds on it. It redefines the way value/quality is assessed as well as created by deciding up-front the firm's performance level on each category performance vector (strategy canvas) and deciding what to reduce, eliminate, raise, or create anew (Kim & Mauborgne, 2015, p. 25-46).

Inspired by these two theories, (Blue Ocean Strategy and Triple Constraint) this paper suggests the replacement of "quality" with "value" and "costs" with "effort" where effort is defined as the spending of firm's resources (tangible &intangible) denominated as the resource categories suggested by Wernerfelt (Wernerfelt, 1984) as well as Christensen (Christensen, 2013, p. 186): financial resources, people, know-how, technology, relational capital and time.

Since we will analyze digitally enabled decision making at the farm level, we will work with the variant where the scope is fixed and equals with the farm level.

Reformulated this way, the triple constraint theory from project management could be re-phrased as: *time & effort will determine the delivered value*. The “effort” construct captures the dynamically synchronized use of resources and could be assimilated as the area of the polygon drawn (Fig 1) by the 6 sides representing the type of resources consumed:

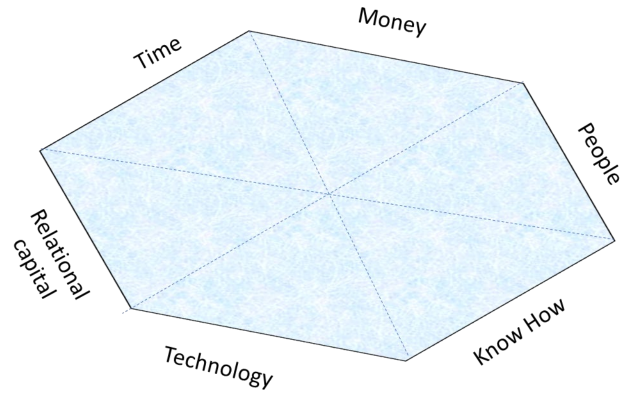

Figure 1. The polygon of resources

Source: Author’s conceptual proposal

In the case of the big crop farms the resource categories present themselves as below:

Table 1. Resource categories available in a big crop farm

Resource Category	Big Crop Farm equivalent
Money	Investment and Working Capital (owned or eligible to access) Grants, incentives, and subsidies Land and buildings as collateral Stocks as collateral
People	Family, employees, and external collaborators
Know How	Tacit and explicit (proprietary/nonproprietary) knowledge of the owner and people involved (employees and collaborators) Accessible sources of advice and consultancy (portals, suppliers’ experts, and consultants) Digital and non-digital Decision Support Systems Business Processes
Technology	Technological Inputs (seeds, fertilizers, crop protection products) and fuel Machinery (tractors, truck, harvesters, implements) & other equipment. Digital Applications and Equipment Owned and rented lands and buildings as means of production
Relational Capital	Affiliations to agricultural associations, Buying cooperations, Financing framework agreements, Trading affiliations, Registered Brands, Any other relationships with suppliers, distributors, customers, authorities (APIA*, AFIR** contracts/projects)

Source: Author’s own elaboration.

*APIA - Agency for Payments and Intervention in Agriculture (government agency)
**AFIR – Agency for Financing the Rural Investments (government agency)

Decision making

Spetzler and his colleagues state that decision making is the most powerful tool to shape our future thus it is important to have quality decisions and they identify six prerequisites of a quality decision (Spetzler et al., 2016, p. 12-17): the appropriate framing of a decisions (purpose, scope, perspective), an adequate number of creative alternatives, relevant and reliable information, clear values and tradeoffs/preferences, sound reasoning and commitment to action. In the case of complex decisions, they recommend usage of a decision model (Spetzler et al., 2016, p. 99) to which sound reasoning is applied.

To better understand decision making in a farm we should consider the major influence that knowledge has on the process and thus its outcome (Bratianu, 2019). Considering the family business nature of the farms and how the organizational knowledge is stored and shared we could start by using the SECI model (Nonaka, 1994) given the very high weight of the tacit knowledge that is relied on when taking decision. Very often this tacit knowledge is recognized by farmers when they say that they are doing things the way they saw their parents and sometimes even grand parents did.

Moving beyond the tacit vs explicit knowledge paradigm that could explain decision making in the farm, the knowledge fields theory (Bratianu & Bejinaru, 2019) provides a very good framework to explain the connection between decision making and knowledge. The three fields of knowledge: rational, emotional, and spiritual and their transformations reflect very well the process witnessed in many decisional situations in the farm where the emotional and spiritual field of knowledge are strongly represented (Bratianu et al., 2020b) and often overpower the rational knowledge, a phenomenon that Braun (Braun et al., 2018) called it heuristics.

Methodology

This paper is the outcome of the review of the relevant literature (decision making, knowledge dynamics and digital agricultural decision-making systems), the analysis of the most popular digital platforms in the Romanian big crop farms as resulted from the author's practitioner experience in the agribusiness domain as well as a conceptual process based on metaphorical thinking.

To facilitate the literature analysis the VOSviewer version 1.6.17 (van Eck, & Waltman, 2010) science mapping tool, was also used (Iliescu, 2021; Paiuc 2021).

The knowledge metaphor construction method (Bratianu & Bejinaru, 2019) was used to draw on the known (the source) domains of the "hexagon surface", "pyramid" and its "height" as well as the "diamond" to the target domains of "effort", "performance" and "value creation". The diamond metaphor was used for its source domain meanings of lasting and sought after value, shaped through a conscientious effort of chiseling each face and ultimately also inspired by the adjoined pyramid representation.

Results and discussions

The Scopus database search done on January 24th, 2023, based on the keyword "agriculture 4.0" generated a corpus of 314 articles.

The keywords of this corpus of articles were mapped with VOSviewer (van Eck & Waltman, 2010) and revealed a number of 936 keywords out of which 148 met the minimum requirement of co-occurrence of 2. To force thematic clustering the co-occurrences criteria was moved up to 5. 26 keywords made the threshold. Before generating the final map of this set of materials, the duplication of terms for “internet of things” and “iot”, “smart farming” vs “smart agriculture” and “precision farming” vs “precision agriculture” were eliminated for a more meaningful link structure in the map as shown in figure 2. The strongest links are between “agriculture 4.0” and “internet of things” followed by “smart agriculture” as well as “precision agriculture” suggesting the deterministic connection between “agriculture 4.0” and “internet of things” as well as the overlap between “agriculture 4.0” “smart agriculture” and “precision agriculture” close to confusion and interchangeability among the terms. Not surprising, another strong link in the map is between “agriculture 4.0” and “industry 4.0”.

The links in the map are substantiating the narrative that Agriculture 4.0 is based on the internet of things and will bring solutions for smart farming through enhanced precision agriculture leveraging especially the other industry 4.0 technologies: sensors, cloud computing and artificial intelligence with its equivalent manifestation forms of machine learning and big data.

A new search in Scopus for articles containing “agricultural decision support systems” as a key word yielded a corpus of 2131 materials in total (articles, conference papers, reviews and book chapters) since 1985 to date, dominated by computer science articles (21%) while agriculture (16,2%) came in third preceded by environmental sciences (17,1%). Narrowing the search to the past five years a corpus of 853 materials was obtained with a similar pattern of domains. After cleaning up the keywords list for duplication the resulting map of 61 keywords with more than 5 co-occurrences out of a total of 2620 keywords is shown in figure 3.

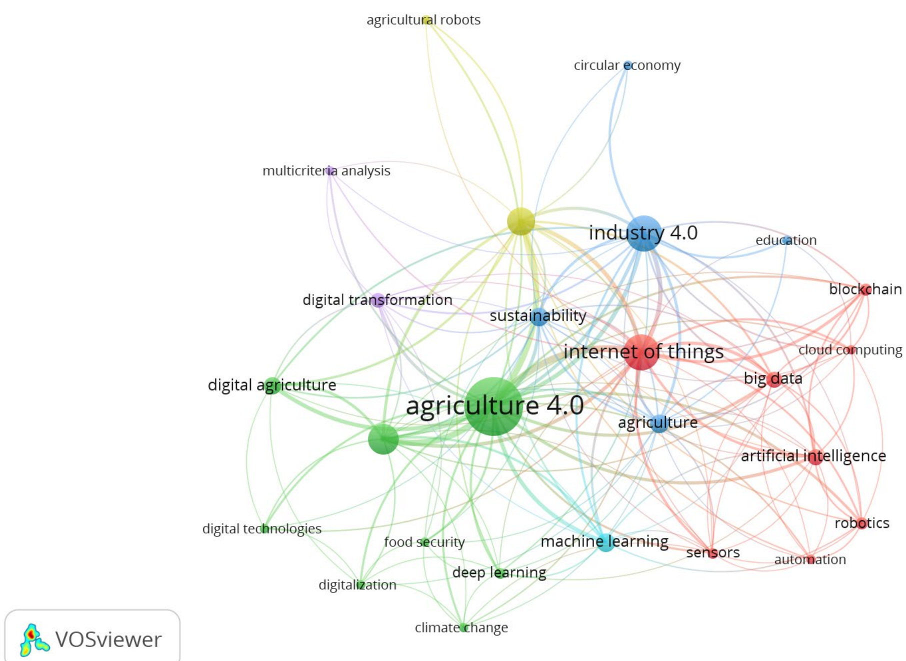

Figure 2. Map of articles containing “agriculture 4.0” with 5 co-occurrences

Source: Author’s own research Scopus, January 24th, 2023.

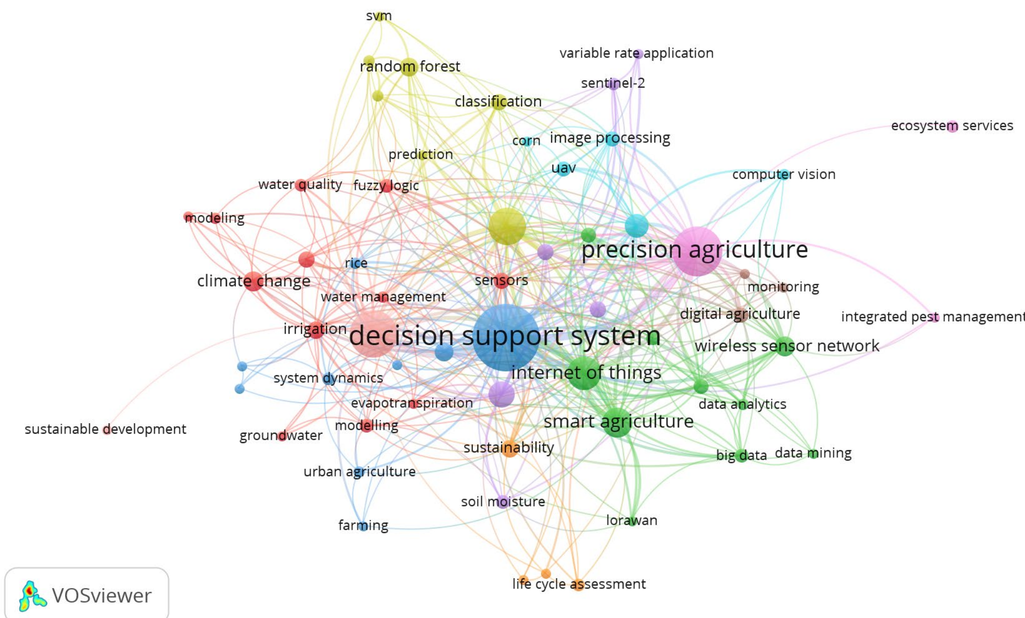

Figure 3. Map of articles containing "agricultural decision support systems" with 5 co-occurrences
Source: Author's own research Scopus, January 24th, 2023.

A decision support system is defined as a smart system that answers to specific operational demands of potential users aiding their decision making while relying on raw data, documents, and/or models (Abbasi et al., 2022). Furthermore, Abbasi and her colleagues in their structured literature review (Abbasi et al., 2022) of agriculture 4.0 provide a list of the ways digitally enabled agriculture is adding value:

a. improved agility through real time monitoring and possibility of intervention,
b. more environmentally friendly process by reducing consumption of fuel, nitrogen-based fertilizers, pesticides, and herbicides.
c. better resource utilization efficiency by growing the output and reducing the usage of energy, fertilizers, pesticides, and water input.
d. time and cost savings through automation of activities (sowing, irrigation, treatments, harvesting)
e. better asset management through real time surveillance to prevent theft and reducing down-time by faster parts replacement and anticipative maintenance.
f. prevent product fraud related to adulteration, counterfeit and artificial enhancement (traceability).

This is consistent also with extant agriculture 4.0 literature (Klerkx et al., 2019; Saiz-Rubio & Rovira-Más, 2020)

A decision support system will be deemed useful if it helps decision making aimed at delivering each of the added value contributions listed above. For decision support systems providers, these become product design guidelines for their tools and platforms while for farmers these are evaluation criteria in their quest for enhanced decision making aimed at performance augmentation. The decision support system is influenced by the organizational culture and the vision of the company to become a learning organization (Bratianu, Prelipcean & Bejinaru, 2020a; Bratianu et al., 2011).

An enriched understanding of the agricultural decision support systems domain is obtained by looking at the seminal qualitative and quantitative work done by Rose and his colleagues in the UK (Rose et al., 2016) that lead to the formulation of the uptake theory and identified the 15 factors that influence the adoption and usage of decision support systems or tools. The uptake model posits that adoption and usage of decision support systems will be judged primarily by the systems performance and relevance, the direct and indirect trust (peer recommendation) a farmer has in the system, as well as its cost and compatibility of the system with the habit of the farmer. Age, type of farming, digital literacy level and size (scale) of farm might stimulate or inhibit the adoption readiness, while marketing activity intensity and any help to fulfill compliance needs will enhance the probability of adoption.

Saiz-Rubio & Rovira-Más with their review (Saiz-Rubio & Rovira-Mas, 2020) complete the understanding of the decision support systems illustrating the information-based way of management for advanced agriculture. They also found that maps-based systems are the most adequate for agricultural decision support platforms and advocate their standardization. Further challenges and opportunities for agricultural decision support systems could be found in Zhai and his colleagues review (Zhai et al., 2020).

The three most popular digital platforms used in the management of the Romanian big crops farms are presented in table 2 while also mapping the type of resources that are managed through modules available in the respective platforms:

Table 2. Digital agricultural platforms used in the big crops farms in Romania

	Vantage	Crop360	Isagri
Description	https://vantage-ro.com/	https://crop360.agricover.ro/	https://www.isagri.ro/
Time	• Geoscan	My Farm • Remote Crop Monitoring through Indices (Vegetative, Humidity, Pest alert) • Field Access scheduler	
Money		• Credit 360 • My Farm - Contracts (land rental)	• Arendas (land rental contracts)
People	• FramTrack	• My Farm - Contracts • My Farm - Field Access	• Arendas (land rental contracts)
Know How	• Trimble Farmer • Geoscan	• My Farm (Indices, Weather, Field Access, Pest Alert) • News	• Geofolia • Fito sanitary codex • eLMID
Technology	• FarmTrack • Geoscan	• My Farm (crop monitoring/fleet monitoring/works scheduler)	• Farmtrack
Relational Capital		• Credit 360 -financing • Input360 - inputs • My Farm - Contracts • E-shop	• Arendas (land rental contracts)

Source: Author's own research and elaboration.

The primary goal of these decision support systems is to provide support for correct real or near real time decisions aimed at improving farm output and efficiencies that are best measured through financial measures. Therefore, combining the illustration of the rephrased version of the triple constraint theory (the resources polygon) with a vertical representation of the financial performance we could obtain a pyramid like graphical representation in figure 4:

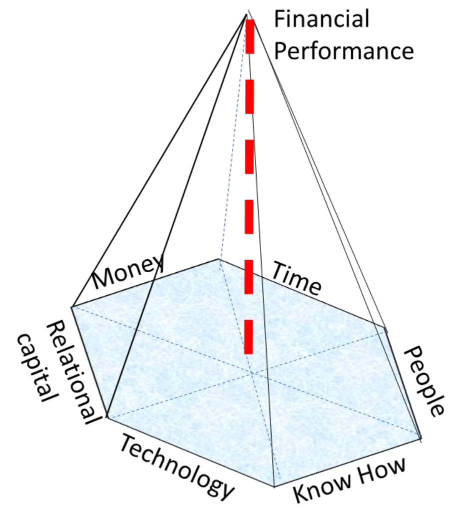

Figure 4. Combined representation of the polygon of resources and the financial performance

Source: Author's own conceptual proposal.

At a further assessment of Abbasi's (Abbasi et al., 2022) list of value added by agriculture's digitization and digitalization two clusters emerge: business efficiency and environmental impact as illustrated in table 3:

Table 3. Clusters of the benefits of agriculture's digitization

Business Efficiency	Reduced Environmental Impact
• Improved *agility* through real time monitoring and possibility of intervention • Better *resource utilization efficiency* by growing the output and reducing the usage of energy, fertilizers, pesticides, and water input. • *Time and cost savings* through automation of activities (sowing, irrigation, treatments, harvesting) • *Better asset management* through real time surveillance to reduce down-time by faster parts replacement and anticipative maintenance.	• More *environmentally friendly process* by reducing consumption of fuel, nitrogen-based fertilizers, pesticides, and herbicides. • Prevent product fraud related to adulteration, counterfeit and artificial enhancement (*traceability*)

Source: Author's adaptation after Abbasi et al. 2022.

These clusters suggest the need of considering them further as two different types of added value. Corroborated with Kaplan's recent review of the Balanced Score Card (Kaplan & McMillan, 2021) following the August 2019 US Business Roundtable that also inspired an earlier McKinsey quarterly article on stakeholder value (Goedhart & Koller, 2020) this paper proposes a further development of this metaphorical model and balance financial performance with the ESG performance. The new model is deemed to be a more balanced value creation model as illustrated in figure 5 and the proposed name is: *The Value Creation Diamond.*

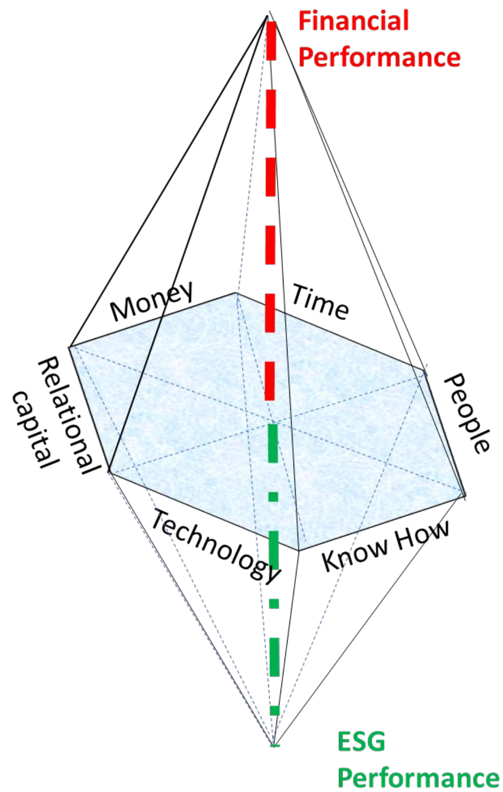

Figure 5. The Value Creation Diamond

Source: Author's own conceptual proposal.

Conclusion

Management decisions in the agriculture 4.0 farm are aided by the usage of digital companions that monitor crops, facilitate asset management and digitally enable decision-making. The aim of these decisions is to increase farm output create enhanced efficiencies and reduce environmental impact, other words create sustainable value (Goedhart and Koller, 2020; Bowman & Ambrosini, 2007) for all the stakeholders of the farm as a firm.

The Value Creation Diamond is a metaphorical tool able to illustrate the interdependence between the use of different resources. While it is inspired by extant literature on strategy (Bratianu, 2022; Bratianu & Lefter, 2011; Porter, 1985) and strategy measurement and operationalization (Kaplan & Norton, 1996, 2004; Kaplan & McMillan, 2021) it is a novel and easy to understand graphical representation of the managerial imperatives to balance between financial and non-financial objectives.

The model could be used by both practitioners and educators in their current activity as a blueprint in the decisional process of an organization as well as an educational tool to illustrate the synergies in the existent literature on firms' performance.

This paper has showcased the digitally enabled big crop farms and applied inductive reasoning to draw the model, but further research should aim to explore possibilities eventually using deductive reasoning to explore its reapplication to other types of farms, firms as well as public and non-governmental organizations.

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