How does artificial intelligence help to avoid disputes in construction?[1, 2]

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INTRODUCTION

The construction market is a collateral market, in fact, it will represent about "$10.3 trillion per year in 2020"[3] and this number will continue to increase over the years. This industry is currently undergoing a revolution. Indeed, with the arrival of artificial intelligence, the means put in place to manage these new constructions are changing, rapidly and constantly improving. One of the biggest problems is workplace accidents on construction sites that have increased considerably in recent years. "In the U.S., the number of deaths on site has risen 34 per cent since 2010. In Japan, around 300 deaths and more than 15,000 injuries were recorded in 2016."[4]

The construction field involves huge constructions, representing very high costs, also involving many people interacting with each other and then representing many different personal interests. To carry out these various construction projects, companies operating in this field must use many machines, generally requiring qualified operators to operate them. However, new constructions need to be more and more precise and complex with fewer and fewer qualified operators. This issue must also take into account a safety issue for workers working on these sites. Fortunately, these issues can be resolved or at least reduced thanks to technological advances in this field, without which many disputes regularly arise and can have very significant consequences in the performance of the contract.

Construction machinery[5] is machinery used to assist or replace human beings on construction tasks? There is a multitude of machines that are used on construction sites like heavy equipment vehicles, we can name cranes, bulldozers, concrete mixers, excavators or dump trucks. Today

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[3] Market Reports Store. (2015, February 17). Global Construction Market Worth $10.3 Trillion in 2020 (50 Largest, Most Influential Markets). Retrieved from https://www.prnewswire.com/news-releases/global-construction-market-worth-103-trillion-in-2020-50-largest-most-influential-markets-292235961.html

[4] Artificial Intelligence in Construction Equipment. (n.d.). Retrieved from https://constructionexec.com/article/artificial-intelligence-in-construction-equipment

[5] Heavy equipment. (2018, August 1). Retrieved from https://en.wikipedia.org/wiki/Heavy_equipment

other equipment is used such as drones or algorithms that analyze a huge amount of photographs in order to detect potential flaws and dangers. Intelligent construction machines are therefore machines that make it possible to assist people, but in a more detailed way, in fact, these machines analyze in real time the tasks performed and help workers to work more precisely, more quickly and all this while taking into account the safety around the machine. Sensors are placed all around the machines to avoid an impact between two machines or between a machine and a worker. These machines use artificial intelligence and GPS technology to work efficiently.

		GUILD DEFINITION[6]	CONSTRUCTION EXAMPLES
Project		A special environment created in order to deliver one or several business outcomes, in a frame of a specified resources	Many examples of projects can be mentioned, among them we can find the construction of a building, landscaping, building a road…
Program	Strategic Program	Set of related projects, combined with the purpose to attain the sponsor's future state. This program is linked to a specific strategic goal and its early results influence the further decision-making process	In construction, a strategic program can be defined as a set of projects. The company wins a call for tenders to build several towers in a defined geographical area, which allows the company to obtain a stronger image and thus increase its legitimacy in the sector.
	Operational Program	Interdependent constituent projects, aiming to affect sponsor's day-to-day operations	Operational programs is a way to gain credibility within sponsors, by launching advertising campaigns on the performance of their construction, their respect of deadlines, the state-of-the-art technology they use
	Multi-Project Program	Created interdependence of constituent project in order to receive benefits from the synergy	This occurs when several companies work together for the same purpose, for example, construction companies install elements that facilitate the installation of electrical and plumbing equipment, which then allows the furniture elements to be properly equipped.
	Mega-Project	Project with a significantly larger scale than the	Many mega-projects are taking place around the world.

[6] GUILD OF PROJECT CONTROLS COMPENDIUM and REFERENCE (CaR) | Project Controls - planning, scheduling, cost management and forensic analysis (Planning Planet). (n.d.). Retrieved from http://www.planningplanet.com/guild/gpccar/introduction-to-managing-project-controls

		typical sponsor's projects have	The Middle East and Asia are in the first position in this field, such as the construction of airports, the construction of the Burj Khalifa, tunnels or the Three Gorges Dam in China.
Portfolio	Portfolio of Projects	Is an investment portfolio, where the main aim is to minimize risks and maximize returns	Project portfolios and asset projects often obtained through multiple calls for tenders. Their role is very close, which is why they represent projects already completed and projects in progress as well as the selection of projects. Major construction groups such as Vinci or Bouygues choose the buildings on which they decide to get involved based on the advantage it offers them. Their objective is to obtain the maximum benefits while improving their brand image. This type of group chooses its projects according to their construction capacity and the resulting benefits.
	Portfolio of Assets	Owner or contractor has a portfolio of assets, that mean set of resources, which are dedicated to the projects, with the aim to generate those resources into the most desirable return.	

Table 1: The construction industry as a Project Portfolio[7]

Information Assets	Documentation, software, data, requirements, plans, designs, techniques, methods, processes, procedures, patents, objectives
Human Assets	Project manager, qualified workforce, engineers, site managers, IT operators
Physical Assets	Construction equipment (cranes, dump trucks, excavators, graders, etc.), UAVs and technological tools
Financial Assets	Banks, private investors, regional aid (Europe, Country...)
Intangible Assets	Architects' plans, operating licences, software, patents technology, manpower

Table 2: The assets of the construction[8]

[7] By Author

8 By the author

These resources must be used by project managers while putting these new intelligent machines into operation, which then greatly reduce the risks due to human clumsiness. Indeed, most disputes and accidents on construction sites are due to the human factor, which cannot be as precise as a machine programmed to perform a task.

"Disputes are one of the main factors which prevent the successful completion of the construction project. Disputes are associated with distinct justiciable issues and require resolution such as mediation, negotiation arbitration."[9] Disputes are regular in the construction world, but they can have significant repercussions such as the cancellation of the contract, which can compromise the entire integrity of the project. This is why construction companies must put up barriers to these disputes.

Figure 1: Root cause analysis about disputes that can appear because of the equipment[10]

In the construction industry, there are many causes of disputes that can arise, but in the equipment industry, it is possible to avoid some disputes thanks to the project manager. Indeed, the problems of safety, timeliness and quality are the ones that stand out the most from the point of view of the equipment. These problems can be caused by the company providing the equipment, by the fault of the people using the equipment or even by a lack of technology in this type of equipment. This paper aims to understand the disputes that the project manager may encounter regarding the use of this equipment on site and how the project manager can avoid these disputes by using new technologies and Artificial Intelligence.

[9] Cakmak, E., & Cakmak, P. I. (2014). An Analysis of Causes of Disputes in the Construction Industry Using Analytical Network Process. Procedia - Social and Behavioral Sciences, 109, 183-187. doi:10.1016/j.sbspro.2013.12.441

[10] By the author

- How does this equipment affect the life of the project?
- How equipment and I.A. can resolve these disputes in the construction field?
- How resolving these disputes can avoid a potential breakdown of the contract?

Keywords: Construction industry / Artificial Intelligence / Technology / Equipment / Machine Learning / Construction Assistance / Connectivity / Efficiency / Disputes / Construction fleet

METHODOLOGY

Step 1: Problem recognition, definition, and evaluation

I. As introduced, the purpose of this draft is to understand:

- How project managers of construction companies deal with disputes.
    1. *Contractor-related disputes*[11]
    2. *Design related disputes*[9]
    3. *Contract related disputes*[9]

Categories	Sub-categories
Contractor-related disputes	Delays in work progress
	Time extensions
	The financial failure of the contractor
	Technical inadequacy of the contractor
	Tendering
	Quality of works
Design related disputes	Design errors
	Inadequate / Incomplete specifications
	Quality of design
	Availability of information
Contract related disputes	Ambiguities in contract documents
	Different interpretations of the contract provisions
	Risk allocation
	Other contractual problems

Table 3: Common causes of disputes by categories[12]

11 Cakmak, E., & Cakmak, P. I. (2014). An Analysis of Causes of Disputes in the Construction Industry Using Analytical Network Process. Procedia - Social and Behavioral Sciences, 109, 183-187. doi:10.1016/j.sbspro.2013.12.441

12 Cakmak, E., & Cakmak, P. I. (2014). An Analysis of Causes of Disputes in the Construction Industry Using Analytical Network Process. Procedia - Social and Behavioral Sciences, 109, 183-187. doi:10.1016/j.sbspro.2013.12.441

- In all these cases, disputes result in a loss of time, money or trust.
- Projects managers must implement different solutions in order to avoid these disputes as much as possible.

II. To answer these problems we must find a way to:
- Avoid disputes
- In the event of a dispute, how to resolve it in a way that avoids a loss of money, time or trust.

These are the points on which we will focus in order to find alternative solutions.

Step 2: Development of feasible alternatives.

Below are the various feasible alternatives that a construction company can put in place to avoid disputes that may be due to construction delays, cost increases and defects.

Solution 1: Use the same old methods to draft contracts that are totally suitable for the project[13]

The drafting of the contract must be clear and precise. Indeed, in order to avoid any risk of dispute, the parties must work together to develop a contract that best suits both sides. The drafting of the contract must allow the parties to have confidence in the project and thus reduce the risk of disputes.

Solution 2: Use new techniques in contract management[14] [15]

New techniques to improve contract drafting are increasingly emerging, as software using artificial intelligence and machine learning can read an incredible amount of documents, compare them and thus put them in competition in order to detect problems in contract drafting. This allows for the creation or correction of these contracts, allowing contractors to greatly reduce their risks as a result, the software allows for the reduction of fuzzy information and therefore a complete drafting of contracts. These software solutions are more and more precise and efficient, but they are not totally suitable for each project.

[13] Risk Mitigation In Construction Contracts. (February 2016). Retrieved from https://fr.scribd.com/document/362195223/Risk-Mitigation-In-Construction-Contracts

[14] How AI Is Changing Contracts. (2018, February 12). Retrieved from https://hbr.org/2018/02/how-ai-is-changing-contracts

[15] Applying AI to Legal Contracts - What's Possible Now. (2018, March 11). Retrieved from https://www.techemergence.com/applying-ai-legal-contracts-whats-possible-now/

Solution 3: Use artificial intelligence into techniques and equipment 16 17

The use of new techniques and in particular artificial intelligence in the construction industry also helps to avoid the risk of disputes. Whether in terms of scheduling and allocating resources, designing plans to build efficiently, safety on building sites to protect workers and buildings under construction, autonomous vehicles that permit to work more precisely, faster and with less human hazard, worker assistance equipment, or monitoring and predictive maintenance.

We will have a look at specific attributes that will allow us to assess each of the alternative avoiding dispute in order to analyze them quantitatively. The said attributes are the following.

1. **Costs**[18] attribute refers to the cost of implementing these different alternatives. Money is the spearhead in the resolution of construction disputes, in fact, because of the exceptional proportions that a construction site can take, the implementation of a new alternative can cost a lot of money.

2. **Time**[19] refers to the time required to implement these new attributes. As the saying goes, time is money, so the time to implement an attribute is also significant.

3. **Trust**[20] allows us to see what impact these attributes have on their trust and therefore to be comfortable in their daily actions with these attributes.

4. **Security**[21] makes it possible to analyze the extent to which alternatives make it possible to work while maintaining an optimal level of security.

[16] AI Applications in Construction and Building. (2018, May 29). Retrieved from https://www.techemergence.com/ai-applications-construction-building/

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[21] The Business Benefits of Intelligent Machines. (2018, July 24). Retrieved from http://constructionexec.com/article/the-business-benefits-of-intelligent-machines

5. **Sustainability**[22] is an attribute that makes it possible to see the viability of solutions over time.

6. **Management complexity**[23] represents the difficulty of managing these different alternatives. How managers adapt their daily behaviour to these solutions.

7. **Innovative**[24] does not represent the degree of innovation but the result that results from this solution. To what extent this result changes habits and is therefore innovative.

8. **Risk**[25] that are related to the use of these attributes. What risks arise on a daily basis with these solutions.

9. **Flexibility**[26] what these solutions have, how they can be adapted to different situations.

Step 3: Development of the outcomes and cash flows for each alternative.

To perform this analyze, we will use multi-attributes decision making to rank each attribute of our alternatives solutions from best to worst. We will give a score of 1 to the best option and 0 for the worst one[27]

We will use a comparison method to rank these criteria from 1 to 9.

As the rank classification indicates, we can see that the most important attributes are security, cost and finally trust. On the contrary, the attributes of management complexity, sustainable and innovative appear to be less revealing, even if this does not mean that they should be totally discarded.

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[27] Planning Planet (Nov-2015) – Guild of Project Controls Compendium and Reference (CaR) – 10.3.3.7 Multi-Attribute Decision Making. Retrieved from: http://www.planningplanet.com/guild/gpccar/managing-change-the-owners-perspective

	Costs	Time	Trust	Security	Sustainability	Management complexity	Innovative	Risks	Flexibility
Costs		1	1	1	0	0	1	1	0
Time	1		1	1	0	0	1	1	1
Trust	1	0		1	0	0	0	0	1
Security	1	0	1		0	0	0	1	0
Sustainability	1	1	1	1		0	0	1	0
Management complexity	1	1	0	1	1		0	0	0
Innovative	1	0	0	1	0	0		0	0
Risks	1	1	1	1	0	0	0		1
Flexibility	0	1	1	1	0	0	0	0	
Total score	7	5	6	8	1	0	2	4	3
Rank	**2**	**4**	**3**	**1**	**8**	**9**	**7**	**5**	**6**

Table 4: Non-compensatory model using Disjunctive[28]

Step 4: Selection of a criterion (or criteria)

The last step of this methodology will be to select the top alternatives that we will find in the next table. We will use a non-compensatory model using a non-dimensional scaling technique. Each alternative solution will be evaluated from good to worse by using 3 colours:

Let's assume this:

GOOD	NEUTRAL	NEGATIVE
1	0,5	0

Table 5: Description of best to worst alternatives notation[29]

We have chosen these attributes because they represent the future of the relationship between the parties and the spearhead of dispute resolution. We will now compare alternatives and attributes to define which elements are most likely to effectively resolve conflicts between contractors. This will allow us to qualitatively rank the options from the best to the worst.

[28] By Author

[29] By Author

Attributes	Alternative 1: Use same old methods	Alternative 2: Use new techniques in contract management	Alternative 3: Use artificial intelligence into techniques and equipment
Costs (8)	GOOD	NOT OPTIMUM	WORST
Time (7)	WORST	MEDIUM	BETTER
Trust (6)	MEDIUM	WORST	MEDIUM
Security (9)	GOOD	NOT OPTIMUM	GOOD
Sustainability (2)	GOOD	GOOD	GOOD
Management complexity (1)	GOOD	MEDIUM	WORST
Innovative (3)	LOW	HIGH	HIGH
Risks (5)	LOW	MEDIUM	LOW
Flexibility (4)	WORST	MEDIUM	GOOD
SCORE	28	20	33

Table 6: Multi-attribute decision-making model[30]

SCORE EXPLANATION

Alternative 1:

It would seem that using the same methods that have proven successful in some measures is a good solution although it is not optimal. Indeed, from a financial, security, and risk point of view, this method works rather well, but we must take into account the time-consuming aspect and the flexibility provided by this alternative.

→ This solution is good for a project manager although this alternative involves some uncertainties about the human factor which can sometimes be hazardous, such as mistakes of inattention.

Alternative 2:

This alternative does not seem to be optimal in most cases. Indeed, the use of new techniques that have not necessarily proved their worth can compromise the drafting of the contract and thus create many tensions between contractors.

→ This alternative is therefore not really revealing and can, therefore, be seen as ineffective.

[30] By the author

Alternative 3:

This alternative can be seen as disruptive but it is already being implemented in many areas, including machine equipment, planning and design software, quality control and site safety. This solution seems the most appropriate since it will make it possible to improve speed, costs (even if implementation and development can be extremely costly) which will eventually decrease, while not neglecting the management and drafting of contracts since artificial intelligence will make it possible to design certain contracts while eliminating the negative effect of the human being but without totally replacing it. Contract management software allows contracts to be drafted and corrected very quickly.

From the point of view of security, time management and trust (which has yet to be earned as many people are reluctant to change) this solution seems to be very interesting.

→ This solution is good for both the project manager and the contract manager, as it improves the life of the project while reducing risky risks and therefore reducing many disputes.

Thanks to the MADM we were able to see the appropriate solutions to our problem and the one that is not. We found that using the old contract management methods worked quite well but that together with the use of New Technologies it could work even better.

In order to answer our problem, the most important attributes are:

- *The use of the same old methods*

- *The use of artificial intelligence in techniques and equipment*

We can now eliminate the second solution because it does not solve the problem effectively and safely.

Following the analysis of feasible alternatives, here are the main attributes:

- **Security:** Do these solutions provide optimal security to avoid disputes?
- **Costs**: Can we avoid an increase in forecasts with these solutions?
- **Time:** Is it possible by using these methods to reduce time wasted in project management?
- **Trust:** Will trust between contractors remain strong?

CONCLUSION: Thanks to the development of our study and the MADM we were able to sharpen our attributes as we went along in order to keep the most revealing.

We are studying an optimal solution here, but it is not perfect and does not necessarily suit all projects.

As the management of construction projects is very complicated, the contract must stipulate very varied and often different clauses between each project. There can, therefore, be many disputes over these contracts and project managers must, therefore, protect themselves by using new techniques.

FINDINGS

Step 5: Analysis and comparison of the alternatives.

We will summarize the decision-making process of the study we conducted in steps three and four using an additive weighting technique that allows us to rank the alternatives by comparing the weight of the attributes with the weight of the alternative. Since we decided to eliminate the use of new techniques in contract management, we are now focusing on our two remaining alternatives that are the use of same old methods and the use of artificial intelligence into techniques and equipment.

	Step 1	Step 2	Use same old methods		Use artificial intelligence into techniques and equipment	
	Relative ranking	Normalized Weight (A)	(B)	(A)*(B)	(D)	(A)*(D)
Costs	2	0,04	1	0,04	0,0	0,00
Time	4	0,09	0	0,00	1,0	0,09
Trust	3	0,07	0,5	0,03	0,5	0,03
Security	1	0,02	1	0,02	1,0	0,02
Sustainability	8	0,18	1	0,18	1,0	0,18
Management complexity	9	0,20	1	0,20	0,0	0,00
Innovative	7	0,16	0	0,00	1,0	0,16
Risks	5	0,11	1	0,11	1,0	0,11
Flexibility	6	0,13	0	0,00	1,0	0,13
TOTAL	45	1,00	0,59		0,72	

Table 7: Additive weighting technique31

This method confirms what we thought in step 4 about how the different alternatives are classified. The use of artificial intelligence in techniques and equipment remains the best solution followed by the use of use of same old methods. However, the use of new techniques in contract management is not neglectable because it has a score slightly below the other two but so we're going to decide not to keep this solution.

[31] By Author

Step 6: Selection of the preferred alternative.

We can now rank our alternatives from best to worst:

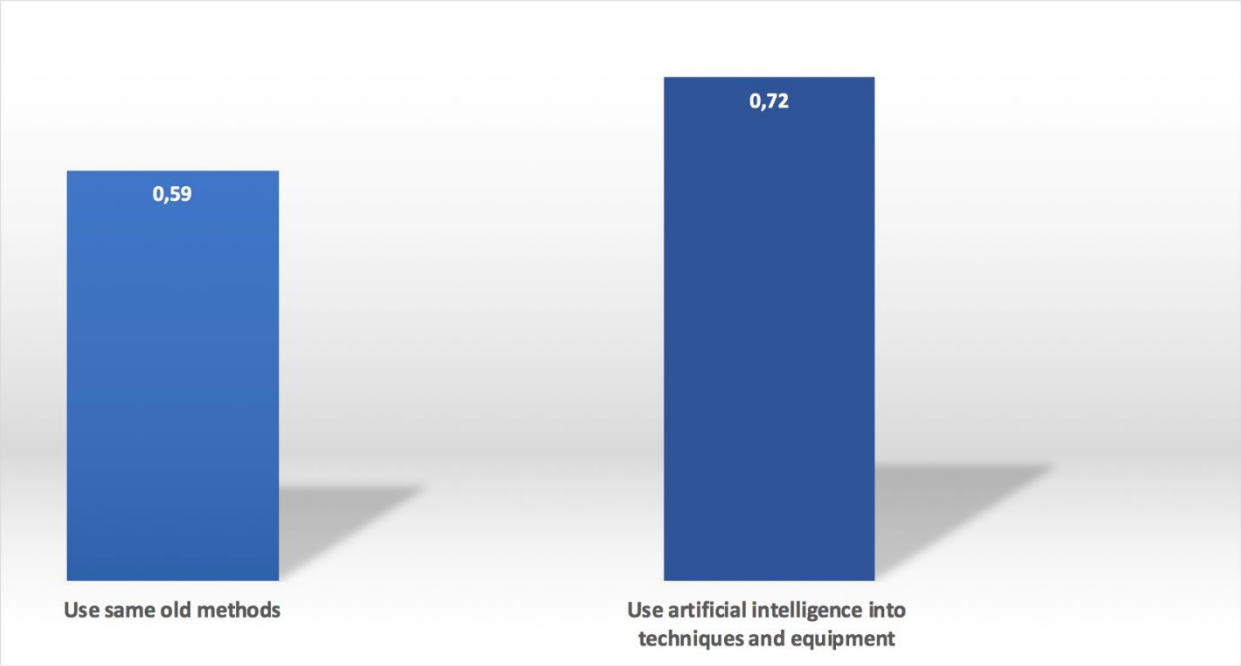

Diagram 1: Ranking from best to worst alternatives[32]

With this classification method and thanks to the study carried out in step 5, we have decided not to keep the alternative of using new techniques in contract management even if they should not be completely neglected. In order to best resolve disputes in the construction industry, the use of artificial intelligence in techniques and equipment seems to be the most appropriate nowadays. The second-best solution is the use of the same old methods. These two alternatives represent a gain in security and time for companies. This allows them to quickly gain an advantage over their competitors.

The alternative use of artificial intelligence is a better choice of 165% compared to the use of new techniques in contract management (33/20 *100) and 118% compared to the use of the same old methods (33/28 *100).

Step 7: Performance monitoring and post-evaluation of results

Now that we have chosen the best solution for avoiding disputes as the use of artificial intelligence in techniques and equipment, we can perform a Pareto analysis to justify the effect of the use of artificial intelligence on the impacts of a dispute.

[32] By Author

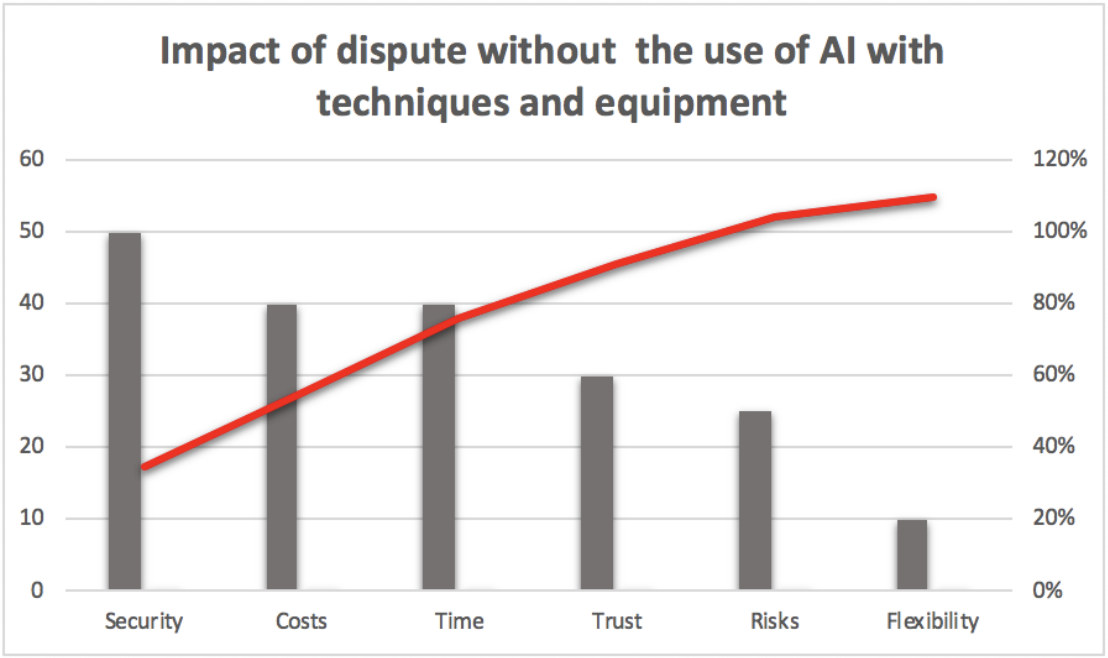

Diagram 2: Impact of a dispute without the use of AI with techniques and equipment[33]

Let's see how the impact of a dispute with the use of AI with techniques and equipment.

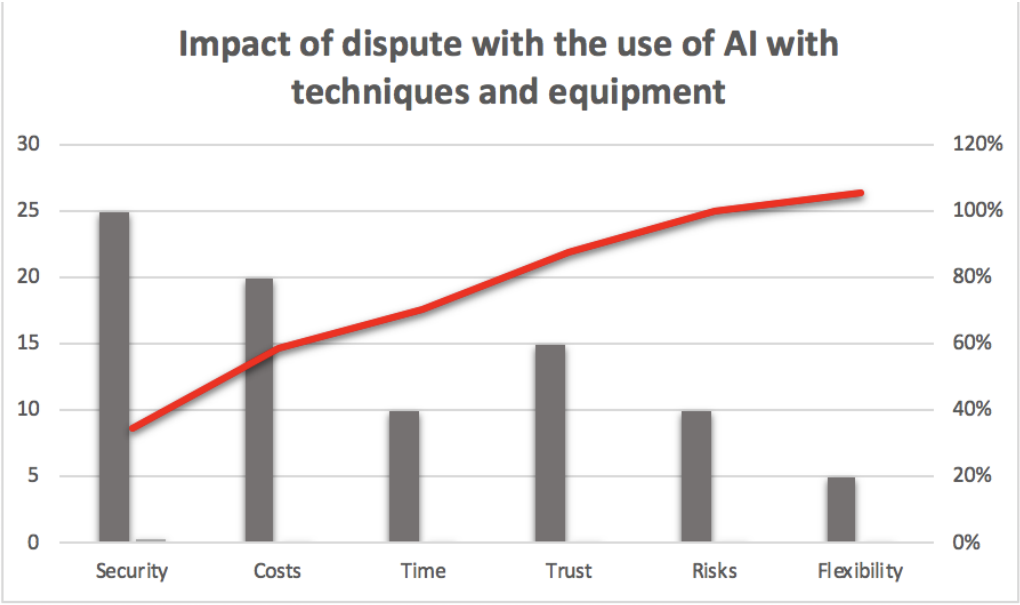

Diagram 3: Impact of a dispute with the use of AI with techniques and equipment[34]

[33] By Author

[34] By Author

We can, therefore, see that when companies use artificial intelligence on their sites and techniques, the disputes are less important. The use of artificial intelligence allows companies to significantly reduce their disputes.

CONCLUSION

The purpose of this paper is to answer the following question: How can artificial intelligence in construction techniques and equipment help to avoid disputes? And what is the best alternative to minimize these disputes.

Through this paper, we have shown the different alternatives to avoid disputes such as the use of old contract management techniques, the use of new contract management techniques as well as the use of artificial intelligence in terms of techniques and equipment. We explained each alternative and developed according to our subject. Through the study conducted we eliminated the option "Use new techniques of contract management" because it seemed to be the least representative in terms of choice. As explained in this paper, AI allows companies in the construction industry to reduce their risk of disputes significantly, both technically and in terms of equipment. These technologies reduce costs, time and risks on construction sites while improving relations between contractors.

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About the Author

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Mathis Catelain is a PGE student at SKEMA Business School currently in Msc project and Program Management and Business Development in Lille, France. He has an international background thanks to a 6-month experience in Brazil (Belo Horizonte) at Fundaçao Dom Cabral and in January 2020, he will go to China (Suzhou) for a 6-month exchange in order to complete his studies.

After graduating from the University of Le Havre, he decided to join a business school in order to perfect his business and project management skills. He will be working for the car manufacturer Renault Alpine in the quality department from January 2019. He is also PRINCE2 certified and is preparing for AGILE PM certification.

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