

# A value-driven perspective to understand Data-driven futures in Architecture

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*This paper reports on an investigation of the potentials of data utilisation in Architecture from a value generation and business creation points of view, based on an ongoing PhD research by the first author. It is of crucial importance to, first, identify what data actually signifies for Architecture, and secondly to explore how the value obtained through data-driven approaches in other industries could potentially be transferred and applied in our professional context. These objectives have been achieved through a qualitative comparative analysis of various cases. Additionally, the paper discusses the multiplicity of factors which contribute to different interpretations and utilisation of data with reference to various value systems embedded into our profession (e.g. design as ideology, design as profession, design as service). A comparative analysis of the existing data utilisation methods in connection with various value systems provide crucial insights in order to answer the following questions: How can data assess values in architectural design/practice? How can data utilisation give way to the emergence of new values for the profession?*

**Keywords:** *Big Data in Architecture, Data-Driven Architecture Design, Data in Architecture Design, Computational Data Design, Digital Value in Architecture*

## **Introduction**

Big Data is a common trend, a buzz word and a broad term concerning large amounts of data that is generated, collected and analysed to provide valuable insights and improve businesses. Many industries have experimented and harnessed the benefits of using Big Data in their businesses, and hence, new business channels and disruptive techniques have emerged which provide the necessary intelligence to elicit, process and make sense of data (Manyika et al., 2013). An analytical report (Manyika et al., 2011) indicated construction sector as the least beneficiary and

falling behind other sectors in the utilisation of data in decision making and knowledge discovery. However, using data in the AEC industry is not new. Data is fundamental to the architectural design and production where both architects and engineers continuously create, modify, share and simulate data. In this respect, data already underlies much of the modern AECO (Architecture, Engineering, Construction and Operations). However, what is new to the industry is the amount of data that is currently available to us and our improved capacity to share, capture, measure, compile, process and translate data

into meaningful and actionable information through smart technologies, enhanced data standards and visualisation techniques (Barista, 2014).

Existing research identifies two immediate problems that impede the adoption of data tools within architectural design firms; first is the lack of efficient means to translate and systematize very large and unknown data sets for efficient use; and second is the lack of knowledgeable data experts within design firms who can intelligibly curate diverse data sources and tools according to the project needs (Deutsch 2015). The proposed paper contributes to the existing research by bringing in the "value" perspectives in order to understand how the different value systems embedded in "architectural design" and "architectural practice" will affect the ways in which data is used and adopted in our profession. The "value" perspective is being raised for two main concerns surrounding architectural profession. The first is the lack of a common understanding of the role architects entail in terms of their contribution to the society. An online survey published in 2012 by the Architect's Journal showed that participants were not aware architect's responsibilities (Thompson, 2012). These results were confirmed by a survey (Samuel, 2015) questioning the value that architects bring inside and outside the profession. There is clear evidence to suggest that this value is not clear neither from the point of view of architects, nor clients or other stakeholders in the sector (Petrie, 2016). The second concern is the extensive concentration on the economic (cost) value of architecture. A recent report by RIBA points out how "austerity and the focus on cost have diminished trust in the value of architects' work" in UK (RIBA, 2015). Reed, the former president of RIBA, indicated to another potential danger of diminishing the quality of life that good design brings and emphasizes the necessity to identify the value created by "thoughtful and responsive architecture". (RIBA, 2011). A recently published report by Arup in collaboration with RIBA addresses the radical transformation in the design of buildings and cities through data-driven approaches and methods

(RIBA, 2013). One of the repercussions of these new approaches is the transformation of our perception as to what counts as a "sustainable" design solution. Sustainable design solutions are now expected not only to be "green", but also intelligent and interconnected and thereby introducing new "economic" and social" value (Kocaturk, 2017).

Architects rely on and are affected by different types of data in their design and decision-making process. Incorporating data into the design process is not a new concept as architects have been doing that since the beginning of the profession (Deutsch, 2015, pn.1). What is new today is the vast amount of digital data that is easily available for low cost and effort (Gupta, 2016). This phenomenon has been described by two fashionable concepts: Big Data and the Internet of Things (IoT). Big Data and the IoT have already influenced new operations and business models to emerge (Manyika et al., 2011) outside Architecture. In order to understand their potential impact on Architecture, it's crucial, as a first stage, to understand what "data" signifies in architecture and for our sector. To this end, this paper identifies "data", primarily, as a driver for the emergence of new values in Architecture and an added-value technology to the built environment and AEC industry at large. The paper specifically aims to contribute to the current Big Data discussion in our industry by synthesising the technological and business potential of Big Data and the IoT (Internet of Things) in order to identify their potential to expand the definition of what we deem as "value" in Architecture.

This paper provides insights into the different components of data-driven models in Architecture with recommendations for possible future implementations. In the following sections, the paper first explores the dynamic and intricate relationship between data and architecture, and reveals patterns of data utilisation in response to varying perceptions and reproductions of design in varying contexts, namely: design as ideology, design as profession, design as service. This provides a deeper understanding of the relationship between how the data is

obtained, the purpose its use, and the value it generates for the processes and products of design. This is followed by a more contextualised discussion on Big Data and the Internet of Things (IoT) and the potential they entail to facilitate the emergence of new operational models in our sector. Finally, the paper reports on the analysis of 8 cases set-up to identify various data-implementation approaches in design across different sectors. This leads to the development of a framework for data implementation and operational model that can be adopted in the architectural profession.

### **Data in Architecture Design**

Data in architecture design has long been associated with the standard resources of technical data such as the likes of Neufert, Time-saver Standards and the Architects' Handbook. These books provide a comprehensive range of technical information for architects regarding the standards and requirements of the different types and aspects of buildings. These data do not have any impact on the design unless the architect consciously searches and applies the selected solution to the design. Data has therefore been seen as simply inputs which architects are required to connect and transform into meaningful designs. Data is mostly understood as constraints and opportunities and rely on architects' reasoning capabilities and institution to influence design decisions.

Data and information utilisation in and for architecture reveals specific patterns according to the varying perceptions and reproductions of design: design as ideology, design as profession and design as service. Architectural design as ideology focuses on the design of forms which respond to perceived social needs with underlying theoretical assumptions. It goes beyond the pragmatic function of architecture and largely associated with the cultural and ideological positions taken (by the architect). The data which drives the ideology is often qualitative, symbolic, philosophical and unquantifiable. The design process depends on the architect's intuition, his personal ideological and subjective standpoint

Most architectural styles are ideological in their core. Design as ideology provides a system of values based on symbolic meaning.

Thinking of architecture as a profession rather than an ideology eludes its deep connection with its social, political and cultural roots, and rather focuses on the economical and market values. Architecture as a profession focuses more on the functional and economic value generated from its pragmatic function. This representation of architecture is relatively contemporary and came into play with the increasing influence of capitalism (Mako, Lazar, & Blagojević, 2014). Also, architecture as profession is mostly driven by the market, which it dictates its principle values and trends (De Graaf, 2015).

Architecture as a service focuses on the design process rather than the artefact. This perspective extends the design process to consider the overall service-life of the product (the building) including after-sales (post-occupancy). Architecture as a service sits somewhere between the previous two (as profession and as ideology). Data that drives architectural design as service usually aims to enhance the overall building performance and quality. In other words, data is aimed at improving value within the performance.

The redefining of data in the above table shows that data serves more than just an "input". Its role extends and allows other values to emerge. It becomes quite clear that value is the main objective when assessing data and that the achieved value is crucial in understanding how data could be employed.

Design as	Data source	The role of data in process	Assessment
Ideology	Intuition, Inherited	Guidance	Symbolic
Profession	Market	Meeting markets need	Market
Service	Process	Evidence	Performance

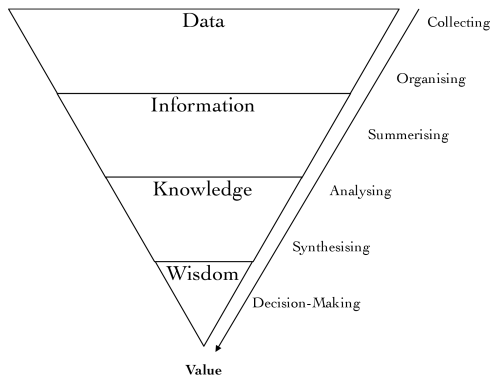
### **Value form Data**

Data goes through different procedures to allow "new value" to emerge. In the past, the role of processing such data has been the responsibility of the architect solely. However, with the rise of digital technologies and the increase of data volume, this

Table 1  
Data in Design as Ideology, Profession and Service

role has changed slightly, allowing the machine to interpret data and to provide new insights. This change affects the role of architects and extends his/her capabilities.

In this context: The Data, Information, Knowledge and Wisdom [DIKW] pyramid provides a preliminary understanding of how various processes affect data. Our own interpretation of the DIKW pyramid is created (Figure 1). The pyramid shows that value is an output of all data processes. Value can be obtained at any stage. The more effort leads to more specified and deeper value.



Architect skillset and intuition are keys for the interpretation of data. A survey carried on by Samuel (2015) showed the different types of architects and their skillsets in the profession. The survey listed four types of architects: Social, Commercial, Cultural and Technological. Comparing these types of architects shows differences in data utilization, the achieved value and the communication of this value.

Data does not disappear when the value is achieved but somehow transform into design decisions, objects and facilities. With the advancement of technology, it is possible to keep track of data and allow it to be reinterpreted in the design process iteratively. An example of this is the reuse of stored data from metadata and sensors which are embedded in spaces to refine the design. The space itself is a prod-

uct of a design decision that is based on data, and at the same time it has sensors that collect data. Data processes are not linear as the output can be reused as an input again.

### **Architect's Role between data and intuition**

When employing data, in addition to reasoning, architects rely on their intuition and that creates their creative impulse (Linzey, 1998). This intuition is intangible and not observed but can be partially described. Intuition determines the difference in the evolution of the design artefact and processes employed by between different architects even when they use exactly the same data.

According to Deutsch (2016) The decision-making spectrum in architecture is either Subjective or Objective based on the input type. Taking design decision based on quantifiable data is considered an objective approach while taking design decision based on unquantifiable data is subjective. The subjective approach is based on intuition and emotions. Figure 2 displays the continuum of decision-making.

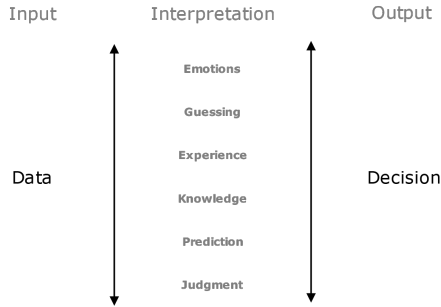


However, this analogy and understanding is not totally accurate. The reason is that data and emotions are presented on the same level as separate interpretations in the spectrum while they are not. Data are not the opposite of emotions. On the contrary, data may as well allow the emergence of new emotions. In fact, data becomes a facilitator of all interpretations in the decision-making spectrum. An example of emotion-based data interpretation in design is Singh's (2013) Emotion-Centred Framework for design innovation. In the diagram below, a refined diagram (Figure 3) of the decision-making spectrum in architecture is suggested. In this diagram data informs different interpretations and eventually allows decisions to take place.

Figure 1  
Value and DIKW  
Pyramid

Figure 2  
Decision making  
spectrum (Deutsch,  
2016)

Figure 3  
The refined decision making spectrum



### ***Big Data, the Internet of things and Data-Driven models in Architecture.***

Different technologies affect the type of different operational models adopted in Architecture (Grobman, 2008; Picon, 2010; Riccobono, & Pellitteri, 2014). These technologies proposed different operations and altered the workflows. An example of these disruptive technologies is the introduction of Computer Aided Design [CAD]. Although CAD was never meant to be disruptive and its underlying motivation in early sixties was to replace the manual drafting process as a cost-effective and efficient alternative, it opened new paths for other technologies to emerge, e.g. increasing use of 3D data, the possibility to share data/information, and new paths for collaboration; which eventually led to the development of Building Information Modelling [BIM] (Isikdag, 2015).

Architecture and construction are complex processes that rely on the use of data. They operate using two-dimensional and three-dimensional data. Architecture handles financial and corporate records, documents, and schedules. In addition to that, the post-completion of the construction process keeps generating an enormous amount of data on a daily basis. The buildings are becoming hubs of sensors, metres and wires. Data is increasingly digitised. What was impossible in handling data before, became probable today with current Big Data technologies. Big Data and the Internet of Things in Architecture can be defined as significant amount of data generated or acquired through the design, the con-

struction and the occupancy of the built environment, including data generated by designers, constructors, the building, and post-occupant users.

There are certain challenges that contribute to adopting Data-Driven approaches in architecture. One of the challenges is the extra time and effort involved in the process (Sailer, Pomeroy, & Haslem, 2015; Deutsch, 2015). The move to Data-Driven techniques is considered a leap in design operations that requires extra training, resources and time, of which the accurate gain is unverified. This situation creates a risk that most architects prefer to avoid. The change in the processes will undoubtedly affect the current culture of architectural profession and education (Deutsch, 2015). Another challenge is the number of disciplines (and stakeholders) involved in the sector where Architecture operates and the need to efficiently address, manage and integrate data across those disciplines (Mahdavi, Martens, & Scherer, 2014, p. 585). Also, Data is seen too abstract and somehow restricting the design process (Deutsch, 2015). The last challenge is due to contractual complexity (Miller, 2012) and the uncertainty around who owns the data and the liability for the project outcome.

RIBA (2013) has identified four general approaches to working with data for architects, urban designers and planners. These approaches are: (i) meeting users' needs, (ii) experimentation and modelling, (iii) analysing data to improve local and national policy making and implementation, and finally, (iv) improving transparency to speed up development processes. These approaches to data handling are proposed as a refinement to what architects already do rather than a change or reformulation of the way architects operate. Also in this report, there is no indication and clarification for the actual operations of these data approaches and the achieved values. We argue that Data-Driven operations have the potential to expand the current use of data and introduce new models of operations in architectural profession. These new models introduce new perspectives and methods of embedding data into the design process.

## Case studies Analysis, Methods and Grounded Theory

The previous sections identified the correlation between data and value. We explained what data mean to architecture and how Big Data affects the architecture industry. We also identified the need to uncover data operations and indicate how value is created. In order to achieve this, various cases have been collected and analysed inductively following the principles and methods of Grounded Theory. This section will describe the selection and analysis of eight case studies in order to reveal the hidden data processes that are employed in the design.

The cases are analysed following two methods: The first is concerned with the process and operation of utilising data to allow values to emerge. This was achieved following the grounded theory methodology. The second is focusing on the value and how the digital data address value. This was achieved following a digital value assessment. The case studies are conducted to achieve the following objectives: Identify the main components of the architecture data-driven operation in design; Identify the data-driven operational models in Architecture Design and the relationship between the architecture data-driven operation components; Identify the types of values that emerged; Propose a structured understanding of the data-driven operational framework.

The first and main method is the Grounded Theory, which is a systematic methodology that permits the construction of theory through the analysis of data (Glaser & Strauss, 1967). It is employed for its capability of explaining complex phenomena, of which there is some ambiguity, and its ecological validity that represents real-life settings. The Grounded Theory is based on continuous coding procedures: Open, Axial, Selective and Theoretical. These coding procedures allow the emergent of themes, categories, concepts and theory through the analysis process. The data must reach a level of saturation in order to consider the theory valid (Charmaz, 2014). The Grounded Theory has its own validation criteria and should be judged according to them. These criteria

are: fit, relevance, workability, and modifiability (Glaser & Strauss, 1967).

The second method is the digital value assessment. This method aims to understand how the digital operation in these case studies enables other types of value to emerge, we present a concept of the Digital Value Equalizer. The equaliser is merely a conceptualisation and representation tool used to show tangible values that are enabled through the digital value. The Digital Value Equalizer offers flexibility as values are added according to the case and can be adjusted according to its impact. Some of the architectural values depend and affect other values and this will affect how the Digital Value is enabling them. This conceptualisation of digital value is adopted in analysing the case studies and coding the obtained value in each case. Figure 4 shows the equaliser in a neutral representation.

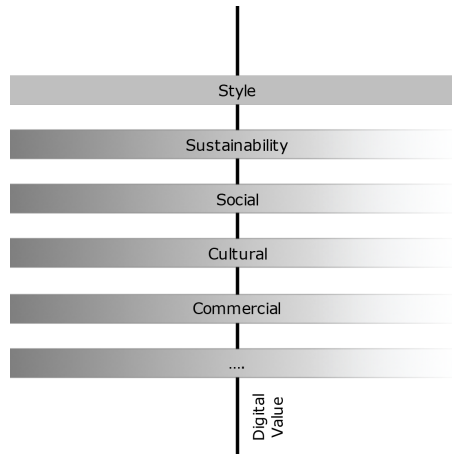


Figure 4  
Neutral  
representation of  
the Digital Value  
Equaliser

Figure 5 shows the Digital Value Equaliser of case study 1. The figure shows the emergence of five values which are enabled by the digital value, these values are Psychological, Social, Economic, Image and Use. Also, the Digital Value Equaliser shows the degree of each value emergence. In Figure 5, which represents the value emergence in case study 1, Economic and Use value are the most achieved.

Figure 5  
Case Study 1 Digital  
Value Equaliser

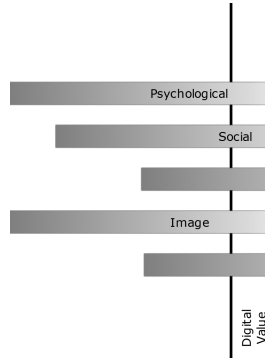


Table 2  
Selected Case  
Studies

Table 3  
Case Studies  
Description

It is important to mention that regarding the definition and the vast domain of Big Data and the Internet of Things, it is almost impossible to find one single case that covers all aspects of the technology. Therefore, it was necessary to consider several cases where data was utilised in a definite scope, in different contexts. The limited scope made each case manageable and consequently, the analysis provided more concrete results. Eight cases had been analysed; each with specific and distinct objectives, collectively covering a wide range of data operations applied in current practice. The cases are cross-sectoral. The case studies selection was a continuous process that concentrated on constant collection and comparison of data/information obtained through these cases until reaching a theoretical saturation of data.

Initial criteria for selecting the cases were established following the rational mentioned above and fulfilling the following:

- The case is chosen from the academic or the practice field
- The case has data implementation through design context with no regard to the phase or level of implementation
- The case provides a solution where one or more architectural or urban elements are involved
- The case has one or more technological methods of data integration, analysis and application

Table 2 shows the selected cases and the industry in which it exists. Table 3 provides a brief description of each case and the theme of data it resembles.

#	Case Study Title	Domain
1	Liverpool1 Pedestrian Visualisation Project	ICT
2	Chicago Energy Map	Governmental Data
3	Campus Information and Knowledge Modelling	Management
4	Four Chairs and All Others	Product Design
5	Human Behaviour and spatial configuration	Office Design
6	Reveal It, My Position	Urban Screen
7	SIG 04	Architecture Machine
8	Hospital Project Using RFID	BIM/ Construction

#	Case Study Title	Description	Data Theme
1	Liverpool1 Pedestrian Visualisation Project	A project based in Liverpool, United Kingdom, where data are collected through a sensors implemented within Liverpool 1 shopping area to expose pedestrian footfalls.	Pedestrian Data
2	Chicago Energy Map	A governmental project of the city of Chicago, United States. This project provides energy information through online portal for occupants through various visualisation.	Open Data
3	Campus Information and Knowledge Modelling	An academic project based in the Georgia Tech Campus. This project utilises a proposed information model that is based on both Building Information modelling (BIM) and Geographic Information Systems (GIS) to assess campus planning and management	Micro Urban Data
4	Four Chairs and All Others	A generative non-linear design project that utilises data and existing 3D models to propose new designs based on the concept of geometry fusion. The data addresses cultural and social aspects	Data to Product
5	Human Behaviour and spatial configuration	An academic project that utilises different methods to collect data about human behaviours to inform the design decision of spatial configuration	Evidence Based Data
6	Reveal It, My Position	A project that utilises occupants provided data to project information through public spaces	Social Visualisation
7	SIG 04	A project that resembles architecture as a machine. It employs an intelligent system (Responsive Framework) which responds to occupant's behaviours and needs, based on specific data exchange.	Responsive Architecture
8	Hospital Project Using RFID	A project which combine the use of Building Information Modelling (BIM) and real-time tracking sensors to manage construction site.	Operational Data

### Components of the Architecture Data-Driven Operation

For assessing the data operations in the case studies through the Grounded Theory, initial themes were used in the Open coding. These themes were identified through a thorough analysis of literature on data-driven businesses outside our industry. These themes have been identified as: Data Sources, Key Activity, Offering, Target Customer, Revenue Model, Specific Cost Advantage (Hartmann, Zaki, Feldmann, & Neely, 2014). Through continuous Open coding of the cases studies, these themes have been gradually refined to suit the studied context and the following themes have emerged: Data Sources, Data Handling, Data Offering, Architectural Value Proposition, Value Channels. Table 4 explains these categories in more details.

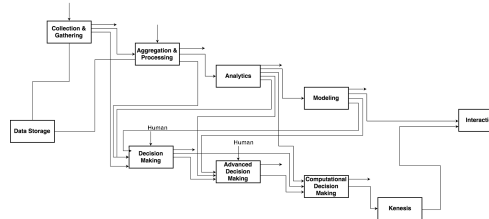
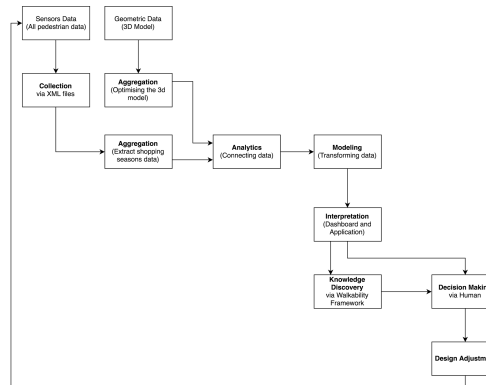
## Data-Driven Operational Models in Architecture

An Axial coding of the case studies was completed to connect the Open coding themes which emerged in the first procedure of the Grounded Theory analysis together by identifying relationships through data operations. The Axial coding had two procedures: Horizontal and Vertical. The Horizontal Axial coding revealed the operation of each case in isolation. The data operation consisted of several components, some components allowed human intervention (e.g. by the architect perspective, or occupant). Each case had been represented in a separate diagram of how these components are inter-connected. Figure 6 shows the Horizontal Axial coding of case study 1 as an example.

The Vertical Axial coding interrelated the analysis from the Horizontal Axial coding. The Vertical Axial coding connected all operations together and proposed a global combined Interpretation of data-driven operational models in architecture. (Figure 7) shows the combined interpretation of data-driven operations. Four different data processes are identified: Collection and Gathering, Aggregation and Processing, Analytics, and Modeling. These processes are interrelated in a specific order. Each one of these processes allows specific intervention of data through a specific application. An example of this is the Collection and Gathering process (Figure 7), it simply allows direct decision making by human. It also provides an output in the form of information, and finally it serves as an input for the subsequent process of Aggregation and Processing. Table 5 provides an initial definition of each process.

Data Sources	The source is identified by the type and hierarchy of stored and streamed data.
Data Handling	The computational process of acquiring, processing and applying data
Data Offering	The output of the Data Handling process in the specific context of the case
Architectural Value Proposition	The values realised in each case. These values are applicable in an architectural context, have the potential to contribute to the emergence of new value systems in architecture, and possibly have an impact on the AEC practice.
Architectural Business Channels	The business strategy which the AEC can adopt. This strategy includes the channels for promoting values in the built environment.

Process	Definition
Collection and Gathering	The simple process of collecting and gathering data of all types with no operations on data.
Aggregation and Processing	The process of selecting and deselecting certain types of data for initially identified purposes.
Analytics	The process of coding, applying algorithms, and connecting certain types of data following set of rules.
Modeling	The process of transforming data from one format into another, such as visualising text and numeric data



## Data-Driven Architectural Operational Framework

The last procedure in the Grounded Theory Analysis is the Theoretical coding. The Theoretical coding revealed the phenomenon represented in a Framework of Data-Driven Operational Models. The Theoretical coding of the case studies proposed four main levels of data implementation, namely: Peripheral Data, Recognition, Intervention and Application. Each level has its component, and each of these components has its properties. Various types

Table 5  
Operational  
Processes of  
Data-Driven Models

Figure 6  
Horizontal Axial  
Coding of Case  
Study 1

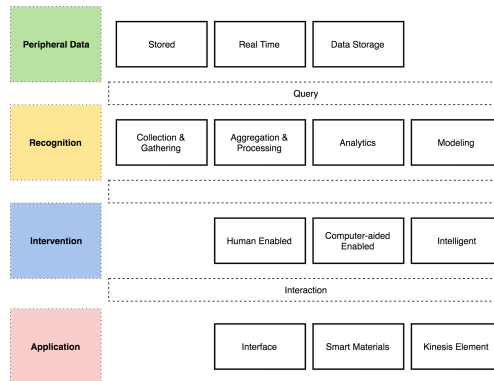
Figure 7  
The Vertical Axial  
Coding of the Case  
Studies

Table 4  
The basic themes of  
the Open coding



of Data were pointed out: Stored, Real-Time and Future, some of these are open data. The recognition of data was identified through these operations: Collection and Gathering, Aggregation and Processing, Analytics, and Modelling. Human Intervention and interaction happens on three levels: Human-Enabled, Computer-aided Enabled, and fully Automated. Finally, the application of data-driven is outputted through: Interface, Smart Materials and Kinesis Architectural Elements. Figure 8 shows the Data-Driven Architectural Operational Framework.

Figure 8  
The Data-Driven  
Operational  
Framework in  
Architecture



## Conclusion

What data means and signifies for architecture and the built environment is a question that needs to be reconsidered. The paper argued that data is more than the representation of the smallest unit in the complexity of a design process. It is a transmittable component of design knowledge and a value generating input for all operations. Instead of proposing a new definition of data in/for architecture - the paper aimed at bringing a value-driven perspective and understanding of data. Following this perspective, and through the analysis of 8 cases across different sectors, the paper developed a new data-driven operational framework for architectural profession.

The use of Grounded Theory aided the construction of new themes and concepts for the develop-

ment of the proposed operational framework. The Digital Value Equaliser - which was specifically developed and used for the case study analysis - revealed numerous (hidden) values that were critical to the understanding of the phenomenon and had been instrumental in building the framework.

While the research is still in progress, the presented results provide a deeper understanding of how knowledge discovery and decision making in the AEC is affected by adopting a data-driven approach. Future work will focus on the levels of automation in data-driven design processes in response to the varying levels of human and machine interventions driven by computational processes.

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