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Infrastructure Management: Development of a Business Model for Transport Infrastructure Interdependencies Management

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Abstract

There is ongoing debate about the value of the benefits of infrastructure systems (specifically those of energy, water & wastewater, transport, waste, and communications) and how to prioritize infrastructure investments to encompass considerations of social, economic and environmental wellbeing. The use of the term 'infrastructure system' is related to interdependencies. Infrastructure systems operating in different countries and cities are interrelated in different ways, but all have a strong relationship to 'transport' – there is a cost and a utility associated with movement. Infrastructure systems are ultimately created to serve individuals, who place a value on them. In order to explore all forms of value realisation – what is commonly termed a business model – the relationship between an individual and the transport system needs to be established. The hypothesis being tested in this paper is that it is possible to identify both the full range of value interdependencies required, and hence to establish a robust business model, for transport infrastructure interdependencies management in terms of social, economic and environmental wellbeing with the other four national infrastructure sectors in the UK (see above). Different research methods were used for each type of value: economic and environmental value were analysed through Pearson correlation coefficient of secondary data, social value was analysed through statistical analysis (mean, median, mode) of primary data. The new business model challenges the monodirectional value creation of more traditional business models by considering the interdependent bidirectional value creation.

Keywords: Business model; Transport management; Infrastructure planning

1. Introduction

The role of infrastructure interdependencies is challenging due to the complexity and dynamic environment of all infrastructures, yet vital for critical infrastructure systems. There is an ongoing debate about the value of the benefits of the five national infrastructure sectors in the UK: energy, water & wastewater, transport, waste, and

communications and how they interact in terms of social, economic and environmental wellbeing. Of particular interest for this study is the development of a business model for transport infrastructure interdependencies management in the UK. Business models aim to understand how value is generated, what costs are likely to be faced and how involved stakeholders capture value. Business models help to understand the sustainability of a business. At the beginning of this paper, business models and their core elements will be defined and discussed. Then an empirical analysis of related data follows. Finally, this paper will present what is a new transport infrastructure business model and how this business model achieves its scope by presenting the value interdependencies with mathematical equations.

2. The Nature of Business Models

Business models have their roots in value. In addition to that, a universally accepted definition of business model does not exist. Osterwalder (2004, p.15) claims that a business model is “an abstract conceptual model that represents the business and money earning logic of a company”. Afuah and Tucci (2001) define it as the core logic of the organization for creating value. Since the organizations compete for customers and resources, a business model should highlight what is different about a particular organization: “how it wins customers, woos investors, and earns profits” (Linder, 2004, p.84). Magretta (2002a, p.43) defines a business model as “a set of assumptions about how an organization will perform by creating value for all the players on which it depends”. Furthermore, Magretta (2002a, p.43-44) claims that management starts “from a theory of the business, from a model as to how the whole system will work to create value”. For better understanding of how Magretta thinks, she provided an analysis of the definition of business model (2002b, p.3-8) and she described it as the reflection of the systems thinking, that is central to management. Business models have to tell a “good story”, and have to be simple and understood by all stakeholders (Magretta, 2002b, p.3-8). Regarding its role, the role of the business model is to target specific outputs by entering certain inputs. Therefore it can be treated as a model. The term “model” is only the standard expression of the experience of the researcher, regarding the nature and the expressions of a phenomenon (Giannopoulos, 2002). A model represents, simplifies and shows relations (Ghuri & Grønhaug, 2010) and describes our understanding or theory regarding how a phenomenon functions (Ruist, 1990).

In the mainstream business and economics environment, business models have technical inputs and economic outputs, meaning they create and capture the capital value using technical elements (e.g. infrastructure). This approach is adapted from Casadesus-Masanell & Ricart (2010, p.197), who support that business model is “how an organization earns money” by creating and capturing value for final users. A definitive definition which includes all the previous discussion is: “A business model describes the rationale of how an organization creates, delivers, and captures value – economic, social, or other forms of value” (Aho, 2015, p.287). The common elements of all definitions are “value” and the “final user”. The logic behind their approach is that, each kind of value can be transformed to capital (economic) value, a logic which allows the assumption of existence of other types of values. This research considers this assumption and accepts the different type of value. Nowadays, a better definition of value is required. The multi-value effectiveness should consider both socioeconomic and environmental factors. There should be a balance between these factors (economic, social, environmental). This balance is a political decision dependent on the needs and the abilities of each society. Additionally, it is challenging to separate the economic, social and environmental factors since they are interrelated. This research, based on its scope (delimitations), stands in favour of sustainability without ignoring the neo-classical economic model.

Business models show the method for converting innovation into value for the business not about delivering value to shareholder. Since a business model is a model, it assumes limited environmental knowledge, as it is only the

understanding regarding how a phenomenon functions under established rules. These established rules are coming either from assumptions (e.g. generalization of the sample with filters) or they can be either limitations (e.g. no access to required data) or delimitations (e.g. the scope may focus only on capital value). To conclude, business models, by definition, focus on value creation and how value is captured. This research defines business models as follows: Business models are how the business is organised and managed to achieve to deliver value to a chosen set of stakeholders and to deliver established value propositions.

The value proposition should create value, but how is value created within the business model? Amit & Zott (2001, p.493) support that, the way business models are constructed is crucial to its value creation. Develop a value framework to create understanding of the business and determine its success (2001, p.500). Within this context, Amit & Zott (2001; 2010) discuss four potential sources of value creation:

- Efficiency, meaning value is created by better processes (2001, p.503-504 & 2010, p.221-222)
- Complementarities, meaning increase value by leveraging products with complementary products from other firms (2001, p.504-505 & 2010, p.221)
- Lock-in, meaning create stickiness, increase switching costs (2001, p.505-507 & 2010, p.221)
- Novelty, (2001, p.508-509 & 2010, p.221)

These four potential sources are suggested by Amit & Zott (2010, p.222) to be used as business model design themes.

Table 1. Business Models in the literature

	Marketing imperative	Internal value creation	External value creation	Growth engine	Linked to each other
Afuah & Tucci (2001)	scope, implementation			revenue, capabilities, sustainability	Yes
Amit & Zott (2001)	transaction content & structure		efficiency, lock-in, novelty, complementarities		Yes
			transaction governance		
Linder (2004)	how it wins customers	how it earns profits		how it woos investors	Yes
Bryson (2017)		Government guarantee schemes & charges of actors		finance development	Yes
		inputs, activities and outcomes that aim to create and capture economic, social and environmental values over the whole infrastructure life cycle			
This paper	Evaluation and use by the key-stakeholders/ final users	Economic value (GVA)	Social & Environmental value creation (welling, emission	Growth by optimization of value	Yes

(social value)

reduction)

The core elements of the business model differ slightly in the literature (see Table 1). The starting point of this research was the conceptual framework of alternative infrastructure models that had developed by Bryson (2017). He presented a design of infrastructure business models, which aligns with the design themes and elements developed by Amit & Zott (2010). The choice of model should depend upon specific criteria. In the literature review, a lot of authors agree that value arises from transaction benefits. Value is created either by reorganising activities to reduce transaction costs (Amit & Zott, 2010, p.222), either by winning customers (Linder, 2004) or through a targeted implementation (Afuah & Tucci, 2001).

Infrastructure business models are defined by iBUILD (2018) as “the system of physical artefacts, agents, inputs, activities and outcomes that aim to create, deliver and capture economic, social and environmental values over the whole infrastructure life cycle”. Instead of transaction costs the environmental and the social cost should be considered. “Consumers benefit from the use of the finished product” (Casadesus-Masanell & Heilbron, 2015, p.3) and “business itself is chaotic human activity” (Casadesus-Masanell & Heilbron, 2015, p.8), meaning that the key-stakeholder who benefits by the product is the final user. Additionally, not all the literature explicitly acknowledges the economic foundations of the business model and by “adopting a different model of value capture, then, is a significant step in understanding the strategic benefits of business models” (Casadesus-Masanell & Heilbron, 2015, p.12). In other words, by transforming the business model from an economic-oriented to a benefit-oriented model, non-economic need coverage is achieved (non-economic value capture).

2.1. The Marketing Imperative of Business Models

Marketing is an imperative component of business models. The final user of the service or product faces aspects of the business model, as the role of marketing is to generate transaction. Value arises from transaction; therefore the role of marketing in business models is crucial and it directly relates to value creation (Vaccaro & Cohn, 2004, p.53). Business models demonstrate potential value and generate resource using marketing (Vaccaro & Cohn, 2004, p.47-49). In addition to that, marketing has to convey the message of the value proposition and so the final user will understand what is valuable about the service or product (Payne & Frow, 2014, p.215-216). The value proposition targets users for whom the organization is creating value (Payne & Frow, 2014, p.215-216). Broadly speaking, the most common value proposition can be divided into three types based on the relation of the price the user pays with value gained (Figure 1).

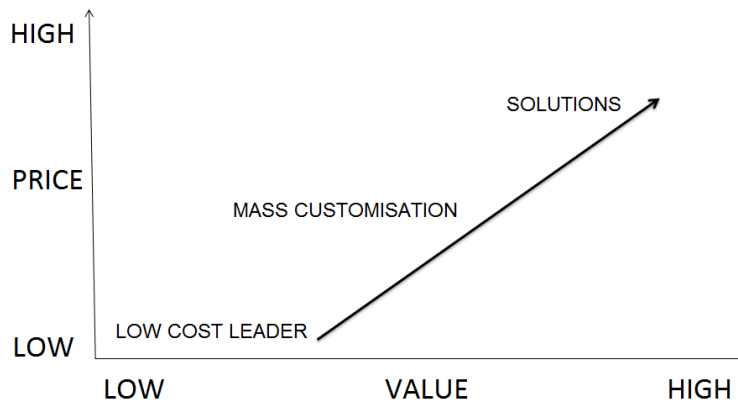


Figure 1. Value propositions

The value proposition of low cost leader is commonly met when value is in cost sensitivity. Low cost leader proposition is accompanied with commoditisation of the service/product, due to the non-differentiation of it (Bordalo et al, 2016, p.502-503). The service/product is readily interchangeable and can only be differentiated via price. This means that, low cost leader proposition requires the exploitation of economies of scale. “Economies of scale refer to the decreasing unit costs when more of the same product is produced or when an identical service is provided more frequently or to more clients” (Crujssen et al., 2007, p.29). The alignment is obvious as the “undifferentiation” of the service/product, which accompanies the low cost leader proposition, in economies of scale is met as “the same product” or as “identical service”. In this case, external value creation is strong either through outsourcing/offshoring or even with globality of sourcing.

Mass customisation is “developing, producing, marketing and delivering affordable goods and services with enough variety and customisation that nearly everyone can find exactly what they want” (Pine, 1993, p.44). A similar definition for mass customization is presented from Mooney et al., who claims that mass customization is the provision of “variety and customisation through flexibility and quick responsiveness” (2000, p.504). After studying the relevant literature, it can be seen that mass customisation value proposition is sought to give final users exactly what they want, at the price they want, and at the time they want it (Pine, 1993, p.44; Mooney et al., 2000, p.504; Duray & Milligan, 1999, p.61) and to “provide sufficient variety in products and services so that virtually every final user is able to purchase a customised product for a mass produced price” (Duray & Milligan, 1999, p.61). It is worth noting that, by customisation it is meant the procedure of uniquely producing of the service/product for each individual not the service/product variety; therefore, final users should be faced as a stakeholder of the business model, since they are involved in the process.

The benefits of mass customisation are many as the customised service/product fits with the unique needs of the final user (Blecker & Friedrich, 2007, p.66; Berman, 2002, p.53). The lower inventory levels allows the process to be efficient throughout the distribution channel (Blecker & Friedrich, 2007, p.66-67; Berman, 2002, p.53). Furthermore, a good service/product, which attracts the final user due to its uniqueness, can have its price justifiably increased (Blecker & Friedrich, 2007, p.67; Berman, 2002, p.53). Finally, opportunities rise due to the continuous friction, in a good way, with the customer, since the market needs can be seen (Blecker & Friedrich, 2007, p.67-68; Berman, 2002, p.53). As it can be seen, mass customisation requires a new business model paradigm. The challenges of mass customisation can be met as a result of operational changes, labour issues or even because of the supply chain, but the critical challenge is, will it appeal to final users?

The last value proposition type is the solutions, which creates exceptional value for the final user. This type of proposition presupposes the creation of mutually supporting value networks and intimate relations between the service/product provider and the final user. According to Miller et al. (2002, p.3), solutions are “integrated combinations of products and/or services that are unusually tailored to create outcomes desired by specific clients or types of clients”. The service/product should fill a specific or unique need of the final user and face a precise challenge, in other words it should provide a solution to a specific problem (Miller et al., 2002, p.3; Ceci & Prencipe, 2008, p.278). The collaboration between the provider and the user for adding value is negotiable and it may involve third parties (Miller et al., 2002, p.11; Ceci & Prencipe, 2008, p.295). The research proposition of this research is between mass customisation and solution, because transport infrastructure should cover the needs of all users (mass customization), but at the same time the final user is a key-stakeholder who has specific problems and has a say in it (solutions).

2.2. Value Creation and the Value Network

Value creation can be separated in two types: internal and external value creation. The internal value creation is achieved within the boundaries of the organization and it is linked with the structure of the organization and the business context (Porter, 1985). The key element of the internal value creation is the value chain.

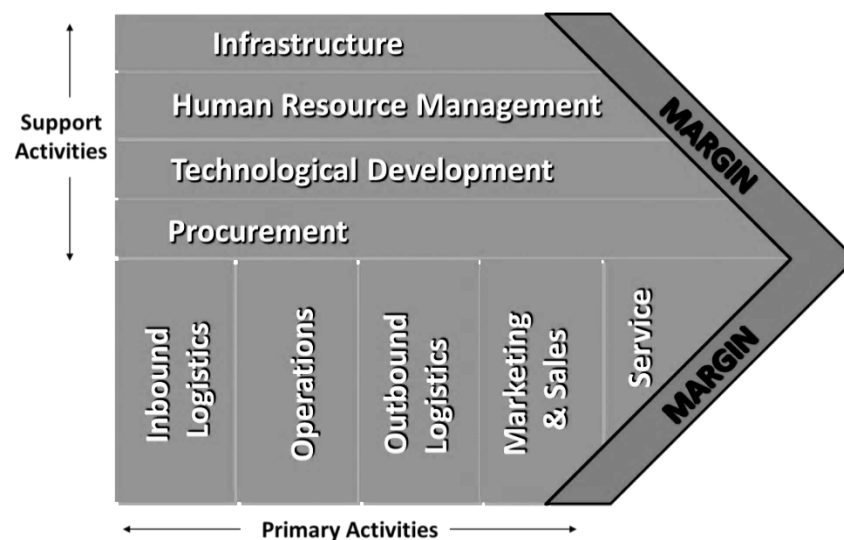


Figure 2. : Michael Porter's Value Chain (Porter, 1985, p.37)

The value chain (Figure 2) creates a list of questions regarding where the core value lies, where core value creating competences/activities are, which channels should be chosen and who controls these channels (Porter, 1985). This means that the core relationships, including customer relationships, and value structure, including cost structure, should get defined.

The external value is achieved by deconstructing the value chain, through value erosion from integration and the collection of upstream suppliers, downstream channels to market, and ancillary providers that support the business model (Christensen, 1997). The value propositions in a value network can be virtual, integrated or in between (hybrid) based on the involvement of third parties. The virtual value proposition happens when the total value created by the third parties and provided to the customer through the firm (e.g. Uber Technologies). Integrated value propositions are very rare or even not possible nowadays and happen when the total created and

provided is by the same firm. Hybrid value propositions are the most common with the involvement of one or more third parties. Typical hybrid value propositions are co-creation (firm customer relations to create value), outsourcing (third party service provision), off shoring (third party manufacturing) etc.

Based on the theory a definition of the total value (both internal and external) and its proposition is required. The co-creation is the most proper value proposition for the new infrastructure business model since it considers the final user as a key stakeholder.

Business model, as discussed, have their roots in value. The common elements of all definitions of business models are "value" and the "final user" (key-stakeholder). The concept of value is used to determine the importance, worth or usefulness of the phenomenon under investigation. The challenge of valuing something arises when there are different types of values within the phenomenon. The comparison achieved through the exchange. The exchange allows getting a quantitative sense of value, when the perceptions of value are qualitative.

Historically, the concept of value is linked with money (economic value). Adam Smith in his book *The Wealth of Nations* (1776, p.48) claims that "the real price of everything, what everything costs to the man who wants to acquire it, is the toil and trouble of acquiring it. What everything is really worth to the man who has acquired it, and who want to dispose of it or exchange it for something else, is the toil and trouble which it can save to himself, and which it can impose upon other people." Additionally, Adam Smith knew that the price (money) of anything does not represent its real value, but a nominal one. This nominal value was mostly affected from the exchange process without deeper understanding of the real value. John Stuart Mill, in his book *Principles of Political Economy* (1848), focussed more on the factors affecting the value and he rejected Smith's approach. He concluded that value is distinguished from economic value which is worth estimating in money terms, while value is worth estimating in goods in general. These goods may have a non-measurable value (qualitative) that cannot be defined through money. Mill's conclusion was closer to the truth, as this non-measurable value was described as an environmentalist and anti-consumerist value.

The first to rigorously discussed environmental value was the Club of Rome (late 70's to early 80's). They point out, correctly, that air-pollution, deforestation etc. are not included in the economic value, but they suggested, wrongly, the transformation of this type of value to economic value. This transformation is dangerous as it allows people to believe that they can destroy the environment if they pay the right price (exchange value theory). There are limits to this exchange that should be defined considering the destruction of the humanity. The previous discussion has generated a new discussion between the neo-classical economic model and the strong sustainability model. The main assumptions of the neo-classical economic model coming from the mainstream business and economics theory are: individuals create value via rational economic exchange and control (Tversky & Kahneman, 1991). The main assumptions of strong sustainability are: human dependence on ecosystem services (Schumacher, 1973) and the assessment of the coupled human-environment systems is based on a vulnerability framework (Clark et al, 1990). It can be seen that, the value perceptions of business and economics oppose the value perceptions of sustainability. The problem is due to the different ethics of each discipline.

Bonnedahl and Eriksson (2011) did a detailed analysis of alternative discourses on economic organization in their research. Their starting point is that business & economics' approach interests for shareholder wealth followed by short term viability and sustainability's approach cares for the resilience followed by long term viability (all living, now and in the future). So, according to Bonnedahl and Eriksson (2011, p.168), in an economic organization the mainstream business and economic approach targets profit, consumption and growth and it focuses on the efficiency of its activities. On the other hand a strong sustainable organization targets stakeholder satisfaction and focuses on multi-value effectiveness via intra- and intergenerational justice (Bonnedahl & Eriksson, 2011, p.168). This definition accepts the multi nature of value. Nowadays, a better definition of value is required. The multi-

value effectiveness should consider both socioeconomic and environmental factors. There should be a balance between these factors (economic, social, environmental). This balance is a political decision depending on the needs and the abilities of each society.

So how can we calculate the value of an infrastructure, and for whom it is beneficial? Infrastructure is a shared-resource system collectively owned by its individual users. The individual users act independently in this system, according to their own needs. Sometime, this action opposes the common good of all users, since the individual users do not consider the rest of society. This phenomenon can be described as “The Tragedy of the Commons” economic problem. The tragedy of the commons argument states that if the individual user tries to maximize possible value from a non-excludable and rival resource then this resource will be depleted (Hardin, 1968). The tragedy of the commons can be considered in relation to the value of infrastructure, especially regarding sustainability. The commons dilemma stands as a model for a great variety of infrastructure problems in society today, either directly as water, energy or indirectly through externalities of infrastructures as transport, communications and waste. The water supply infrastructure is affected directly from the water resources deficit from water pollution, over-extraction of groundwater and waste water due to irrigation (Shiklomanov, 2000). Energy sources, and more specifically non-renewable energy sources, pollute the environment mostly, but not only, through their combustion (FAO, 2018). Common externalities of transport infrastructure are pollution, carbon emissions, and traffic accidents (Dunber & Levitt, 2008). Communications has many negative externalities; these include radiofrequency and microwave radiations which affect the health of the humans (Szmigielski, 1996). Waste infrastructure is an externality by definition, as exposure to various waste is highly associated health risks (Turley et al., 2013). These problems and externalities should be considered when an infrastructure interdependencies network is designed. To proceed, the tragedy of the commons argues that individuals will use the communal infrastructures to excess for getting all the benefits with little cost. The infrastructure is communally owed, but some of its elements (e.g. houses, cars, RF antennas etc.) are privately owned. The solutions provided by Hardin (1968) were: privatization of the commons and/or government regulation. By privatization of the commons, it is meant that the ownership of the infrastructure will be transferred to individual users, assuming that they will behave rationally focusing on the long-term sustainability of the infrastructure. The assumption of an individual’s rational behavior is very common in business research, but when it comes to mass society is not widely accepted. By government regulation it is meant the creation of limitations on the usage of each infrastructure. It is obvious that these solutions are not applicable for critical infrastructures (e.g. water, transport, communications), as it is hard to restrict access to them. Furthermore, by isolating critical infrastructures, the society is driven to the risk of losing access to them. Since the problem of infrastructure cannot be solved by privatizing everything and restrictions, we ought to solve it by making all critical infrastructure and its elements communal. The challenge of the collective behaviour can be sorted out by considering the individual user as a rational key-stakeholder and not as the final user (e.g. infrastructure sharing, value co-creation). To do so, it should create an environment /context/business model that will allow the individual user to act as a key-stakeholder, but at the same time there should be tools to control the rationality of the decisions of the individual. In transport infrastructure management the core value lies on the environmental, social and economic and the core relationships of the business model can be represented in an illustration with e.g. lines/connections.

2.3. *The Growth Engine*

Infrastructure managers are looking for growth entities. Value creation generates resources and the sustainability of the business model depends on resource generation (Manda et al, 2015). Business models are shaped by and executed within an external environment, meaning the resources are generated by the external interface between business and environment. By identifying where resources can be generated it can be seen that a part of the value

generated does not come from direct resources, but comes, indirectly, from the infrastructure interdependencies. To conclude the key target of the business model is to generate or access resources through its value creation from all possible sources.

In this research the transport infrastructure value creation is not purely economic. So the growth engine should focus on sources (e.g. investors, partnerships etc.) of resources who are interested in the social and environmental value too and in the indirect value creation. The stakeholders were taken from the literature (Bryson, 2017) and they were divided based on their interest in environmental and social value or not:

- Public sector, Public-Private Partnership and Third sector (Voluntary) have major interest in the environmental and social value
- Private sector, Trust and Co-operative/Community Ownership were considered have major interest in the economic value

3. Research Methodology and Empirical Findings

A business model is something qualitative and value is something quantitative, so they were linked by conceptualising the value interdependencies as functions with different value variables. The individuals were considered as key-stakeholders and not as end users. The model was separated in three parts based on the type of value - economic, social and environmental. These values were studied individually and then different research methodologies used to study their interactions and create mathematical equations. The dependency was studied inductively by looking at the correlation between each type of value of the different types of infrastructures. Correlation between two variables does not necessarily imply causality (Field, 2009, p. 619-620). The two variables can certainly be related with causality, but may not be. For example, both may be affected by a third variable. Therefore, it is obvious that a rough or superficial interpretation and use of the correlation may lead to wrong conclusions. Since the correlations do not imply dependency (Field, 2009, p. 619-620) this was confirmed by the theory. In any other case, a causal relationship (interdependence) between two correlated variables was verified with a rational assumption. Pearson correlation coefficient was used for this study (Field, 2009):

$$r = \frac{s_{xy}}{s_x \cdot s_y} = \frac{\sum_{i=1}^v (x_i - \bar{x}) \cdot (y_i - \bar{y})}{\sqrt{\sum_{i=1}^v (x_i - \bar{x})^2} \cdot \sqrt{\sum_{i=1}^v (y_i - \bar{y})^2}}$$

Where:

- If $-0.3 < r < 0.3$ there is no linear correlation
- If $-0.5 < r \leq -0.3$ or $0.3 \leq r < 0.5$ there is a weak linear correlation
- If $-0.7 < r \leq -0.5$ or $0.5 \leq r < 0.7$ there is a medium linear correlation
- If $-0.8 < r \leq -0.7$ or $0.7 \leq r < 0.8$ there is a strong linear correlation
- If $-1 < r \leq -0.8$ or $0.8 \leq r < 1$ there is a very strong linear correlation
- If $r = \pm 1$ there is a perfect linear correlation

Of interest of this study is a medium linear correlation or stronger, meaning r equals more than 0.5 or less than -0.5.

3.1. Economic Value

The economic infrastructure interdependencies were investigated by correlating the Gross Value Added (GVA) of each infrastructure with the others' infrastructure GVA. Although the correlations do not imply dependency (Field, 2009, p. 619-620), they can show if any and which infrastructure interacts with another infrastructure based on GVA. The GVA of the Input-Output tables' comparison will show the correlations between each infrastructure (Table 2). The causality is obvious as GVA is the grand total of all revenues which are incomes into other sectors and create dependences.

Table 2. Economic Infrastructure Interdependencies

		Transport	Energy	Water	Waste	Communication
Transport	Pearson Correlation	1	.728**	.921**	.926**	.976**
	Sig. (2-tailed)		.002	.000	.000	.000
Energy	Pearson Correlation	.728**	1	.832**	.594*	.756**
	Sig. (2-tailed)	.002		.000	.000	.001
Water	Pearson Correlation	.921**	.832**	1	.852**	.907**
	Sig. (2-tailed)	.000	.000		.000	.000
Waste	Pearson Correlation	.926**	.594*	.852**	1	.918**
	Sig. (2-tailed)	.000	.000	.000		.000
Communication	Pearson Correlation	.976**	.756**	.907**	.918**	1
	Sig. (2-tailed)	.000	.001	.000	.000	

** . Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

The economic value interdependencies were calculated using the last five product by product Input-Output tables of the United Kingdom and applying the method of multiple linear analysis (Kalyviotis et al., 2017). These tables are industry-by-industry tables showing both supply (rows) and use (columns) between every single industry for a given year:

$$Y_{cr} = 0.32 \cdot X_{cr1} + 2.99 \cdot X_{cr2} - 0.35 \cdot X_{cr3} + 5.27 \cdot X_{cr4} + 125.74$$

[where X_{cr1} : value created from Energy to Transport, X_{cr2} : value created from Waste to Transport, X_{cr3} : value created from Communication to Transport and X_{cr4} : value created from Water to Transport; when $X_{cr1} \in [606, 1,765]$, $X_{cr2} \in [0, 380]$, $X_{cr3} \in [411, 1,628]$ and $X_{cr4} \in [43, 82]$].

or using the estimated, with the RAS method (Timmer et al., 2015), product by product Input-Output tables of the years 2000-2014 of the United Kingdom and applying the method of multiple linear regression analysis:

$$Y_{cr} = 1.968 \cdot X_{cr1} + 6.624 \cdot X_{cr2} - 3.718 \cdot X_{cr3} + 10.796 \cdot X_{cr4} - 0.247 \cdot X_{cr5} + 28985.737$$

[where X_{cr1} : Value Added from Energy, X_{cr2} : Value Added from Waste, X_{cr3} : Value Added from Communication, X_{cr4} : Value Added from Water and X_{cr5} : Value Added from Other sectors].

Table 3. Statistical Model Coefficients

Model	Unstandardized B	Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Tolerance	Statistics VIF
(Constant)	28985.737	11728.527		2.471	.035		
Energy	1.968	.429	.250	4.587	.001	.186	5.375
Waste	6.624	1.454	.491	4.555	.001	.047	21.067
Communication	-3.718	.829	-.406	-4.484	.002	.067	14.855
Water	10.796	4.161	.266	2.594	.029	.052	19.072
Other	-.247	.034	-1.506	-7.245	.000	.013	78.340

The values of the coefficients are indicative, as there is major correlation (VIF>10) between the variables and both models cannot be generalized (see Table 3).

3.2. Social Value

The social infrastructure interdependencies were investigated with an interview, where three hundred individuals chosen to be reasonably representative of aspects of the UK’s demography were asked to identify the dependency between transport and other infrastructures. The individuals were asked to evaluate the dependency with an integer between 0 and 5 and the mean, the median and the mode were calculated. Table 4 shows the mean, the median and the mode of the dependency evaluations between the different sectors by the individuals. When two (median and mode) of the calculated values had the same value, then the value was accepted. In any other case, the mean was considered as the accepted value for the dependency. Causality exists since the individuals were asked if they perceive a rational dependency and to evaluate it.

Social value may be defined as a sigmoid curve of the needs covered over time explained with the hyperbolic tangent curve (Kalyviotis et al., 2018).

Table 4. Social Infrastructure Interdependencies

	Mean				Median				Mode			
	Energy	Water	Waste	Communication	Energy	Water	Waste	Communication	Energy	Water	Waste	Communication
Walking	0.16	0.47	0.75	0.79	0	0	0	0	0	0	0	0
Cycling	0.17	0.51	0.76	0.74	0	0	0	0	0	0	0	0
Rail	4.55	0.55	0.80	3.30	5	0	0	4	5	0	0	5
Bus	4.67	0.35	0.76	2.66	5	0	0	3	5	0	0	5
Car	4.67	0.36	0.41	1.59	5	0	0	1	5	0	0	0
Taxi	4.67	0.31	0.47	3.03	5	0	0	3	5	0	0	5
Air	4.72	0.52	0.62	3.88	5	0	0	5	5	0	0	5
Water	4.35	4.41	0.66	2.63	5	5	0	2	5	5	0	5

3.3. Environmental Value

Environmental value is related to the emissions generated. Emissions calculated were translated into estimated emission coefficients for each sector which equal an average sector rate per GDP. This was done with the EXIOBASE which is a multi-regional environmentally extended Input-Output database (reference). In other words, emissions are generated with an almost linear relationship and consequently environmental value has a negative linear relationship with GDP (Kalyviotis, 2018). The economic value interdependencies were calculated using EXIOBASE 3 by correlating the emission coefficients (emissions generated per GDP of each sector) of 48 major economies. The dependencies between the coefficients of the sectors constitute transport infrastructure and the

sectors of waste, water, energy and communications were recorded and presented for transport as total and for the subgroups of air, land and water transport (see Table 5)

Table 5. Environmental Infrastructure Interdependencies

Emission	Transport Dependency	Air	Land	Water
CO ₂	Energy; Communication; Water; Waste	Energy; Communication; Water; Waste	Energy; Communication; Water; Waste	Energy; Communication; Water; Waste
CH ₄	Energy	Energy	Energy	–
N ₂ O	Energy; Communication	–	Energy; Communication	–
SO _x	Energy; Communication; Water; Waste	Energy; Waste	Energy; Communication;	–
NO _x	Energy; Communication; Water; Waste	Communication	Energy; Communication; Water	–
NH ₃	Energy; Communication; Water; Waste	Energy; Water; Waste	Energy; Communication; Water; Waste	Energy; Water; Waste
CO	Energy; Communication; Water; Waste	Energy; Communication	Energy; Communication; Water; Waste	–
Benzo(a)pyrene	Energy; Communication; Waste	–	Energy; Communication; Waste	–
Benzo(b)fluoranthene	Energy; Communication; Waste	–	Energy; Communication	Energy
Benzo(k)fluoranthene	Energy; Communication	Energy	Energy; Communication	Energy
Indeno(1,2,3-cd)pyrene	Energy; Communication; Water	Energy	Energy	–
PCDD_F	(Missing values)	(Missing values)	(Missing values)	(Missing values)
NM VOC	Energy; Communication; Water	Energy	Energy; Communication; Water	–

PM10	Energy; Communication; Water	Energy	Energy; Communication; Water	–
PM2.5	Energy; Communication; Water	Energy	Energy; Communication; Water	–
TSP	Energy; Communication; Water	Energy	Energy; Communication; Water	Energy
As	(Missing values)	(Missing values)	(Missing values)	(Missing values)
Cd	Energy; Water	Energy; Water	Energy; Water	–
Cr	Energy; Communication	Energy	Energy; Communication	–
Cu	Energy; Communication; Water	Energy	Energy; Communication; Water	Waste
Hg	(Missing values)	(Missing values)	(Missing values)	(Missing values)
Ni	Energy	Energy	Energy	–
Pb	Energy; Communication; Water	Energy; Water	Energy; Communication; Water	–
Se	Energy; Communication; Water	Energy	Energy; Communication; Water	–
Zn	Energy; Communication; Water	Energy	Energy; Communication; Water	–
NMVOC (non- combustion)	Energy; Water; Waste	–	Energy; Water; Waste	–

4. Development of the new Business Model

Value creation is crucial to understanding the business model of transport infrastructure and its relationship with stakeholders. The new Transport Infrastructure Business Model is presented in Figure 3 to give a holistic picture of how the value is created and the stakeholders who capture this value. Supported by the academic literature, the interdependencies are designed based on the correlated empirical data and illustrated in Figure 3. The numerical attributions of the economic value in the figure are indicative, since the economic variables used for the linear analysis were highly correlated. On the other hand, social and environmental values were calculated with no correlated primary data and taken directly from existing matrices, respectively.

The environmental interdependencies are only presented in terms of pollutants without any attempt to create a quantitative result. The main reason for this is that the authors did not want to present a pure economic representation of environmental value, which may be used as an excuse for individuals or organizations to damage, or even in some cases destroy, the environment and pay the “right” amount of money as compensation.

In the new business model (Figure 3) on the left part can be seen the stakeholders (growth engine) of the model and on the right the value creation by the different type of infrastructure to air, land and water transport and by transport itself. Green is used to represent the environmental value, red the economic and blue the social value. Additionally the figure shows which type of value each stakeholder captures by connecting them to the appropriate colour line. Representative qualitative information has been placed for each type of value in the business model based on secondary and primary data used.

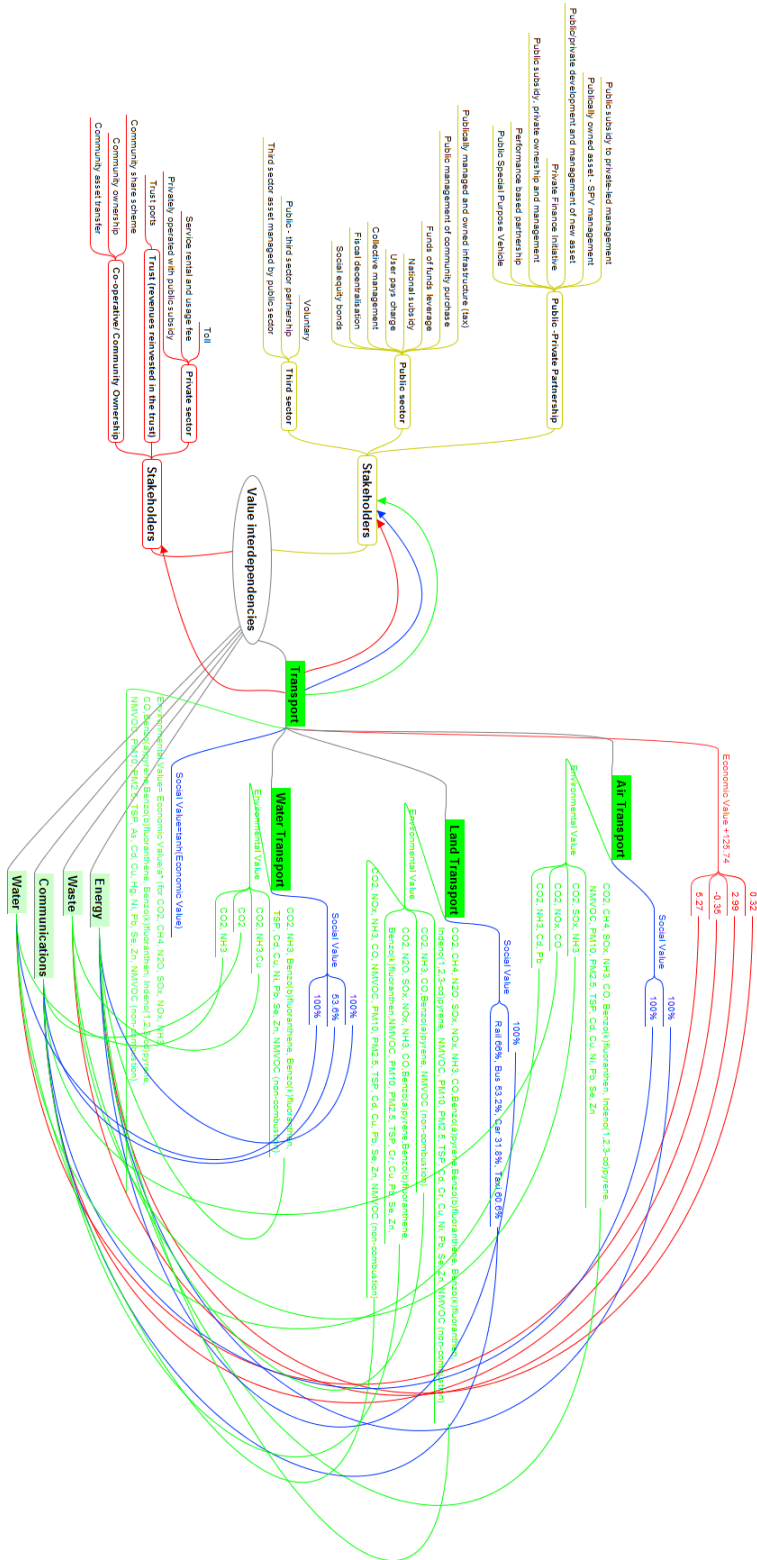


Figure 3. Transport Infrastructure Business Model

5. Conclusions

The dependence of business models on the definition of value and on the use made of them makes them flawed/vulnerable to any change of how the value is defined and to any change of how the end user understands this value. Infrastructure business models are defined as the system of physical artefacts, agents, inputs, activities and outcomes that aim to create, deliver and capture economic, social and environmental values over the whole infrastructure life cycle. Since the relations of the above system is based on the interdependencies, then correlation of the appropriate data was used to identify the economic, social and environmental value connections between the different types of infrastructure.

The general depiction of the relationships between transport, water, waste, communication and energy permits better understanding of how the overall system works by policy makers and hence better decisions on which type of infrastructure to focus on if they want to add value to society.

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