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Strategy for Supply Chain Integration of Autonomous Electrical Vehicles in the Internet of Things

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Abstract: This paper outlines a new methodology for developing strategy for supply chain integration of Autonomous Electrical Vehicles (AEV) to the Internet of Things (IoT). The methodology consists of external architecture and internal design that anticipates the business strategy in the development process. The methodology is designed to anticipate the impact of developments in new road transport technologies, such as Tesla Truck or Tesla Pickup. Since the methodology is designed to anticipate the impact of non-existing technologies, it represents green-field analysis. Green-field is defined as a new and non-existent operation. Green-field strategy architecture in this paper is presented as a process of accepting the world and acting upon that version of the world. The results of the analysis are presented as pathways and outcomes, emerging from the interrelated relationship between AEV and IoT. The emerging methodology is applied through two case studies to evaluate the impact to environment, performance and operationalisation. The methodology proposes architecture and design for integrating AEV and IoT in the supply chain strategy, and a set of new evaluation criteria that promote acceptance of Artificial Intelligence (AI) in the design process. The main contribution to knowledge is a new methodology for integrating AEV and the IoT to the supply chains. The paper applies interplay between inductive and deductive case study and grounded theory approach to build upon the concept of supply chain architecture and contribute to knowledge to the topic of formulating green-field integrated AEV- IoT supply chain strategy.

Introduction

The Internet of Things (IoT) represents the idea of networked objects communicating their data, that can be controlled across other objects, systems and servers. The evolution of IoT represents many opportunities for social and economic interaction in areas such as supply chain management, social media, medicine and energy consumption. IoT provides advanced connectivity that goes beyond machine-to-machine (M2M) communications and applies to a diversity of protocols, domains, and applications. The evolution of IoT represents multiple cyber-physical systems, integrating technologies related to smart grids, smart homes, intelligent transportation and smart cities.

These areas are detrimental in improving transport energy efficiency and reducing greenhouse gas (GHG) emissions. Transportation is one of the fastest growing major sources of GHG emissions in the world. Government and industries are already looking for alternatives to reduce GHG emissions without reducing their competitiveness, by making

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smarter transport decisions. Thus, transportation focus is shifting towards cost reduction and environmental sustainability. Increased usage of new technologies such as autonomous electrical vehicles (AEV) represent enormous potential of integrating IoT technologies to increase the cost effectiveness through intelligent transportations.

The AEV technologies are evolving fast. These developments trigger the question of how can we integrate such technologies fast, safe and effectively. The major obstacles for the AEV industry seems to be the safety, security and the lack of relevant infrastructure and compatibility between standards and policies. The proposed area of research is the design of architectures for technological integration of electrical vehicles in the IoT for optimising the intelligent transport network of the EU. Integrated architectures are required for utilising safely and securely the data from the advanced connectivity of IoT . However, while agile and resilient IoT with appropriate security could create economic value, it also must evolve into a network that humans can appreciate and trust. Hence, these architectures must anticipate privacy, trust and ethical policies.

1. Research Methodology

The research methodology applied, embodies a process of building upon the methods for supply chain decomposition design (Schnetzler et al., 2007, Perez-Franco 2010, Melnyk et al., 2013). The theory building is representative of ideas and concepts conceived as an interrelated, interworking set of objectives that enable the development of systematic understanding of the AEV-IoT strategic dimensions. The research applies directive, conventional and summative analysis to analyse a number of IoT critical problems that are closely related to the emerging strategic dimensions.

2. Aims and Objectives

The aim of the research is to derive with architectures for hierarchically decomposing the AEV-IoT into supply chain integration areas and categories.

The objectives are:

1. To derive with a framework for green-field AEV-IoT supply chain architecture, and
2. To derive with a system for green-field AEV-IoT supply chain integration.

3. Paper outline

The first section of this paper introduces the aim and objectives, the second section reviews the extant literature, focusing on the integration of supply chain operations. Third section presents the research methods and the empirical study. Fourth section discusses the main findings and contributes to knowledge by investigating the question of how green-field business strategy can be formulated to integrate multiple participants in the supply chain strategy.

Literature Review

4. Supply chain system design

Supply chain design is a dynamic concept and interdependancies are related in an individual context. The supply chain structural elements are based a business model representing a structured system. Thus, a hierarchical method can be applied for network design and Analytical Target Cascading (ATC) for deconstructing a complete supply chain hierarchical tree to architect the supply chain design decomposition. Similarly to Perez-Franco (2010) the literature emerging supply chain design decomposition system separates different themes and choices between the nominal and executed strategy (Figure 1).

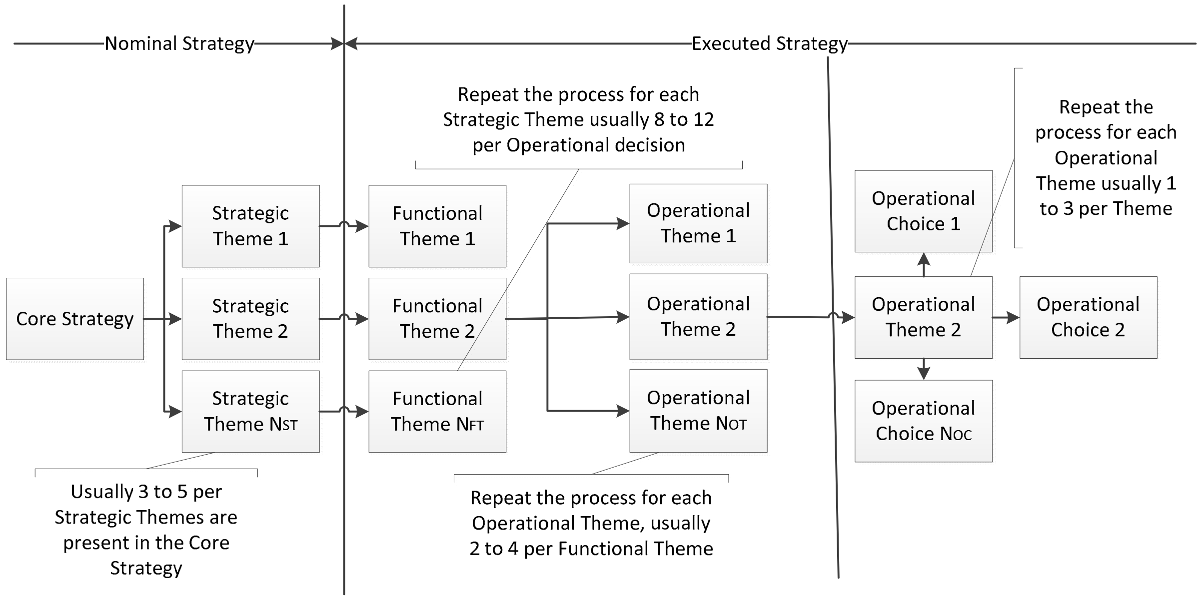

Figure 1: Emerging green-field decomposition system

The literature derived model outlined in Figure 1 represents the basics for the emerging conceptual design. The model enables investigating the actual instead of the desired outcome of the supply chain system, analysed through the activities.

Supply chain integration design

Supply chain design, tactic and operations represent a complex multi-structural decentralised system with active independent elements. These complexities can be addressed by applying engineering systems principles. In addition, qualitative research methodologies can be combined with engineering design techniques (Perez-Franco 2010), starting with the Pugh Controlled Convergence, the Enhanced Quality Function Deployment, the Design Structure Matrix and the Engineering System Matrix. This approach has never been applied for designing green-field architectures and its parameters will require altering to anticipate the complexities of integration. The system decomposition model emerging from existing literature dictates shifting between the desired and executed themes and choices (Figure 2) to design the green-field architecture based on the operational capabilities.

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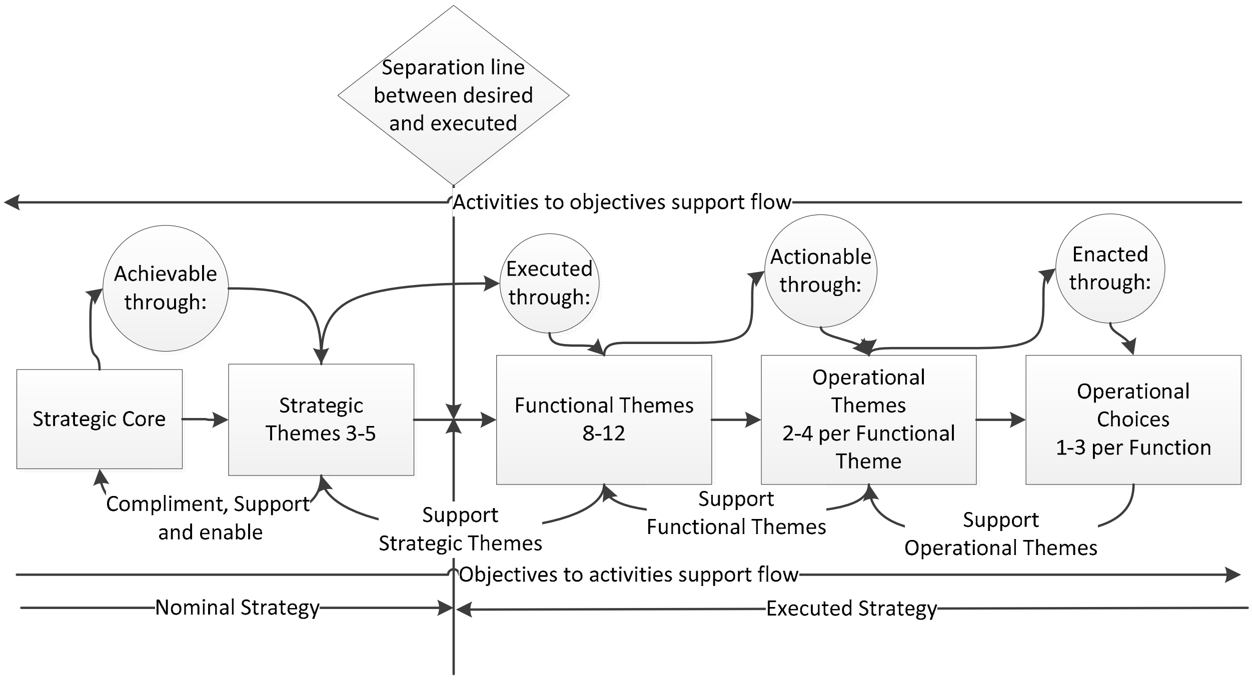

Figure 2: Emerging green-field integration system

The emerging methodology (Figure 1 and 2) consists of decision that affects the fit between capabilities and strategic objectives, in the given supply chain environment. This decomposition and integration system enables the uncovering of the factors driving supply design, however, the factors are strongly context sensitive. Green-field integration systems are influenced by external dimensions and internal elements that are unique to specific business environments. To architect integration, similar and distinct features must be identified along with the underlying factors driving design and shaping the resulting systems.

The critical analysis of existing literature in this paper, concluded that the richness of the supply chain design concept cannot be comprehended or generalised in a single dimension and no single study can explore all factors simultaneously and should focus on various pieces working together to orchestrate an overall architecture design (Figure 3).

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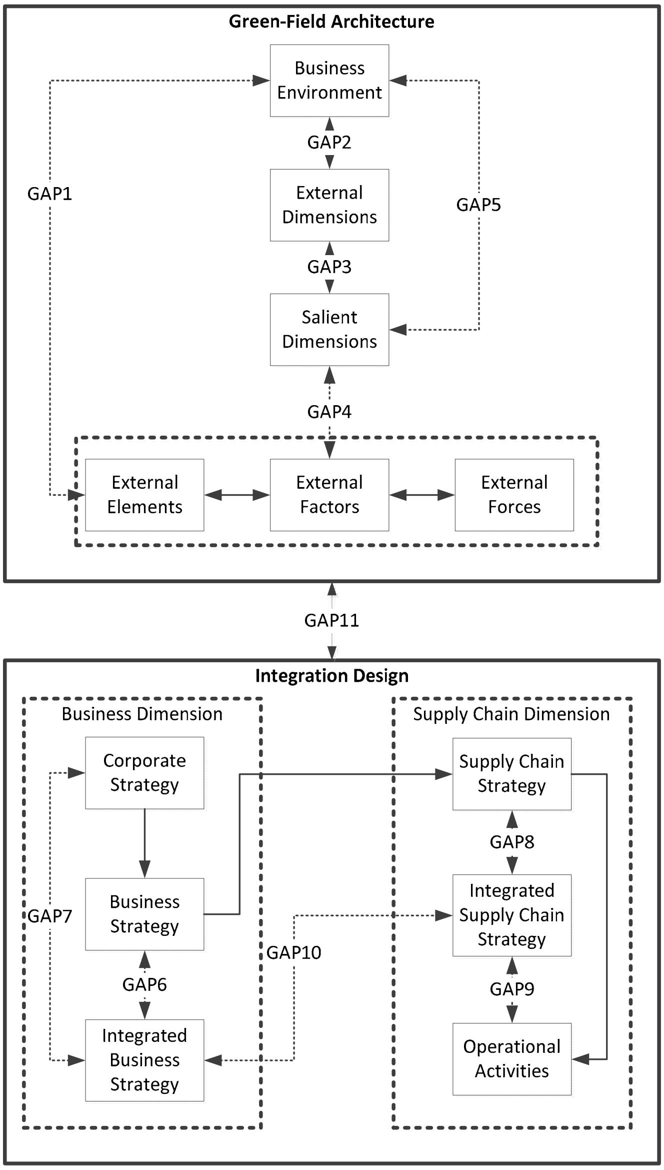

Figure 3: Green-field architecture - external dimensions and internal elements

The identified gaps are outlined in the system (Figure 3) and enable the visualisation of the architectural problem in the attempt to generalise all factors into a holistic dimension.

Empirical study

The research design analyses the integration of multiple participants in the form of a continuum working towards a common goal. The integration design creates many obstacles in the data collection process. Multiple participants in a continuum bring diverse industry interests in the integration. Thus, a comprehensive and systematically structured approach is required to address these obstacles.

The process of addressing the obstacles enabled this study to build upon the preliminary findings (Figure 3) and evaluate the relationship between the dimensions, the business and the supply chain strategy, through:

a) Evaluating the relationship between the multiple participants and business goals,
b) Integrating multiple business goals in the supply chain strategy,
c) Generating theory integrating green-field business and supply chain strategies.

Green-field system architecture

5. Integration architecture

The integration design instigates by requesting the first company (C1) to define their overall business objective as a vision that can be applied to formulate the business strategy concept. This initial business objective defined as a vision, explicitly stated by the first company, presented a vision that is in fact blurred and very complex.

To clarify the idea behind the given vision, a series of open-ended interviews were performed.

The data collected was transcribed and categorised with aims to investigate the relationship between the objectives and the dimensions. The transcribed categories are analysed and evaluated through feedback requests from the interview participants. The aim of the analysis was to identify the ideas behind the statements using open and categorical coding. Table 1 outlines sample quotes illustrating the categories and subcategories identified that relate to the ideas behind the articulated strategy and the dimensions.

Sample quotes from the data collection	
Dimensions	Quotes
Resource dimension (RD)	*Product* 2A) Differentiate through innovation 1B) Introduce by-product materials to the markets 1C) Bring new by-products to the market 3B) Reduce cash to cash cycle 9C) Match production to fluctuating demand
Transport dimension (TrD)	*Cost* 2A) Develop new low cost supply chain 2B) Lower the cost of transport from quarry to customer 1A) Procure high value transport at low cost 2C) Reduce cost of transport 5C) Develop low cost responsive and effective rail transport 9C) Infrastructure planning 3B) …lower distribution cost 8C) Develop finance plan for the required infrastructure 1C) Detailed cost appraisal 7C) Resolve the logistic element of the supply chain 3A) …formulate the supply chain 9C) Shape demand and supply chain
Market demand dimension (MDD)	*Position* 2A) Secure position in the aggregate material markets 3A) Rebalance the market power in aggregate materials 4B) Create trust and acceptance in new markets 9C) Screening defining and targeting individual markets 8C) Scope, identify and target new markets *Profit* 3A) Obtain the highest market share possible *Solution* 3C) …branding innovation

Technology dimension (TxD)	*Solution* 2A) Develop technology… capability …. infrastructure *Position* 5B) Create multiple virtual quarries in rail terminals 2B) Develop locations with virtual quarries 1A)Attain control over the supply chain 2C) Integrate with third party logistics 9C) Optimise the supply chain 9C) Develop engineering and transportation infrastructure
Environmental dimension (EnD)	*Cost* 1A) Reduce environmental costs 3C) Reduce cost by increasing sales margin 2B) Initial cost analysis to assess the potential to reduce cost 8C) Lower operational cost 9C) …improve efficiency

Table 1: Integration categories and subcategories

To identify the precise aspects of these objectives and to formulate the business strategy in a more visual method that could be understood and evaluated, content analysis is applied to scrutinise the statements. The content of the text provided is further discussed with the participants and the strategic goals are associated to the strategic vision (Figure 4). The extracted strategic goals were built into a conceptual diagram during a group discussion to visualise the results (Figure 4).

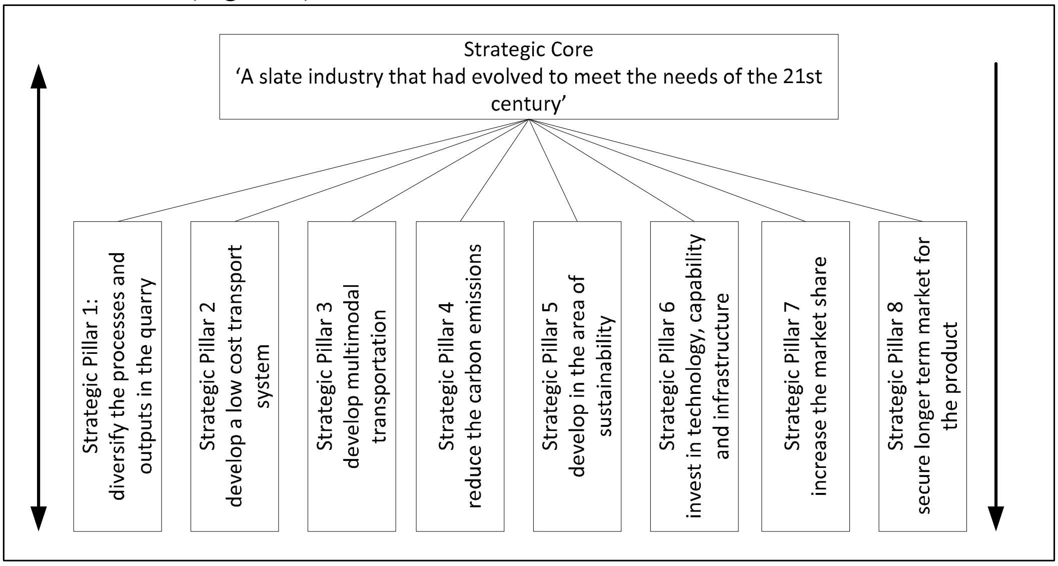

Figure 4: Green-field integration strategy (C1)

The extracted strategic goals in Figure 4 are discussed further with the group and similar goals are merged to keep the ideas not the wording and the conceptual diagram is redesigned accordingly (Figure 5).

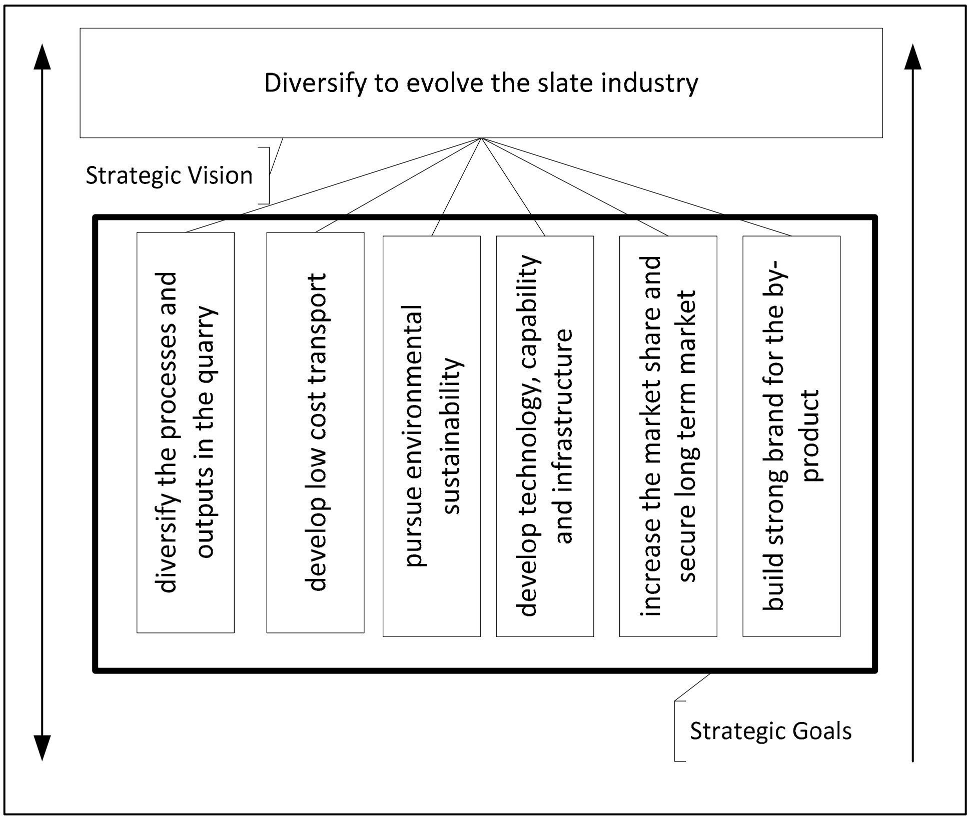

Figure 5: Refined green-field integration strategy (C1)

To prove the validity of the concept as an accurate representation of the business strategy, the conceptual diagrams were presented to levels of employees: directorial (Level A), managerial (Level B) and operational (Level C):

1. Confirm and validate the concepts individually with Level B and through group discussions with Level A and B.
2. Confirm the concepts soundness with Level B to ensure that strategic vision is realistic in the context of company capabilities.

In the first step, the strategic goals were described as a complete conceptual representation of the vision behind the business strategy. However, the second step contradicted the soundness of the vision. Direct field-observations served as an assessment of the essential operations to achieve the expressed vision and goals and disclosed diverse obstacles in assembling a formulation concept. Obstacles were caused largely by identifying insufficient activities in the essential supply chain operations. The business strategy, as expressed represented a statement referring to a seemingly simple idea, but in fact the idea is very complex and represents a vision and several complex ideas. These ideas are categorised and built into a conceptual diagram (Figure 6), alternative categorisations and detailed concept diagram map of the formulation.

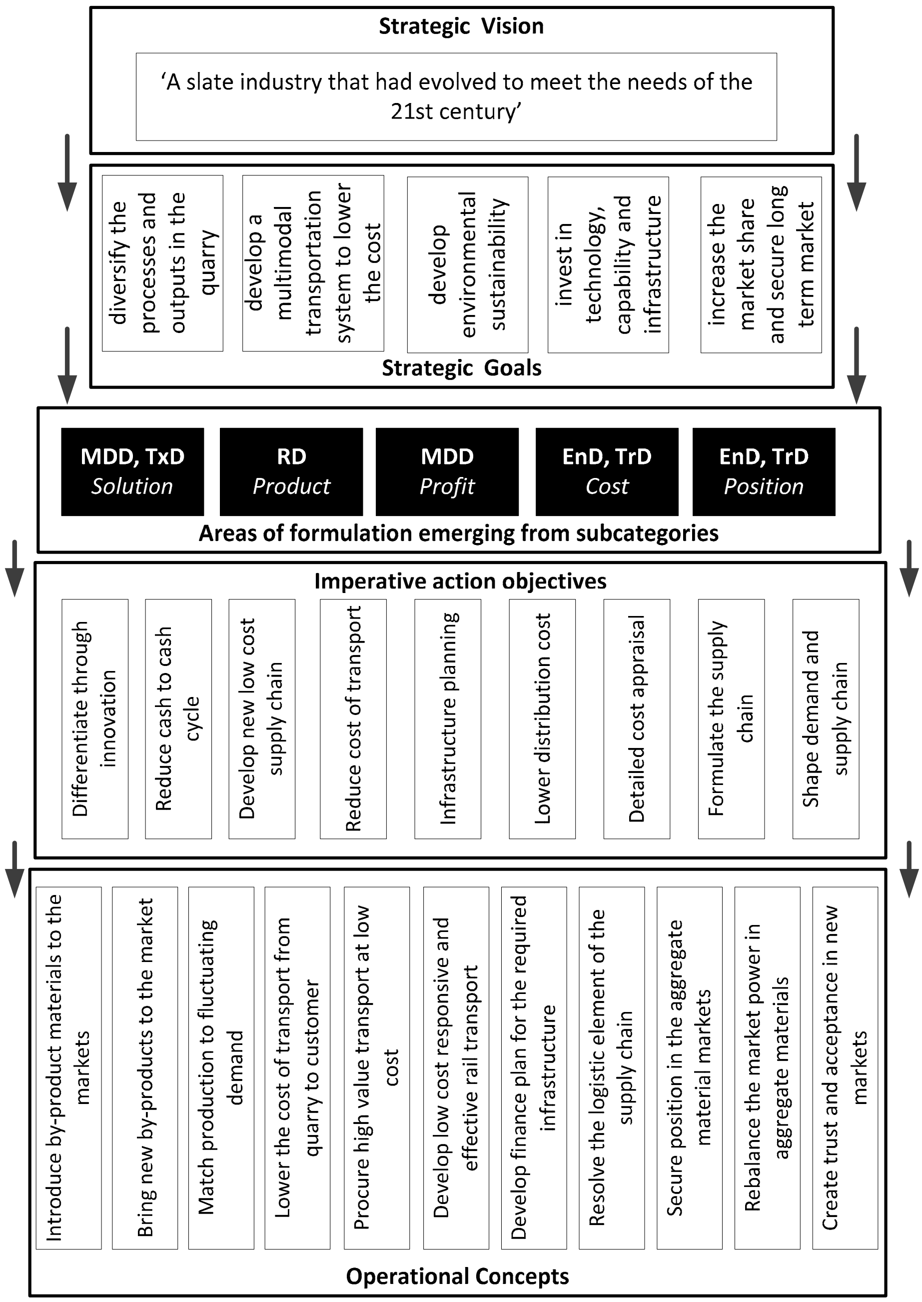

Figure 6: Categorising concepts and objectives into a green-field architecture

Multiple interviews with the sample of participants external to the company, outlined above, derived indications that the business strategy as expressed (Figure 6) represents a vision in the form of a social goal that could bring the revival of a declining industry (Figure 7).

The interviews were followed by group discussions with the external participants and the findings indicated that in addition to the industry revival, the business strategy as presented could also trigger increased economic activity in the area and directly mitigate the external dimensions. The values in these findings in relation to the topic studied are presented in the reverse effect of green-field business integration. The findings indicate that emerging interaction between green-field business creation and the surrounding business environment are interrelated (Figure 7).

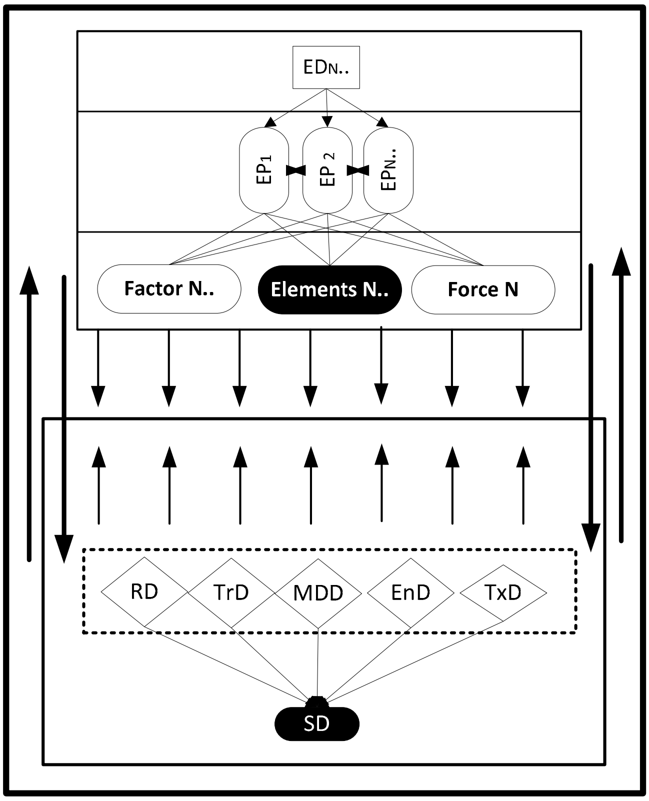

Figure 7: Internal elements of the green-field architecture that effect the external dimensions

This vision provided by (C1) represents accomplishment of a number of ambitious strategic action objectives (Figure 6). However, the vision objective can be accomplished only by achieving operational (imperative) action objectives (Figure 6). In the case of (C1): lower product price, environmental sustainability; or determination to achieve a goal; *'greater market share'*, *'have a low cost transport'*.

The field-observations and interviews with Level B are aimed at extracting the operational activities required for executing the stated vision and goals. The outlined process determined that the business strategy is a true representation of (C1) desired goals. However, the process of investigating the operational activities, created a great deal of uncertainties regarding whether the stated business strategy is a true representation of the (C1) operational abilities. The strategic vision and goals can only be implemented through the operational capabilities and the lack of operational capabilities resulted in the stated vision and goals not been implemented, because of lack in assets, logistics capabilities, transportation infrastructure and know-how, but also because of culture. The culture of 'go it alone' is perceived as the first required change for formulating a supply chain strategy.

To relate these findings, this simulation confirmed that formulating a supply chain strategy by simply applying the operational strategies of the industry participants would not give the desired results and the lack of strategic alignment would represent a form of outsourcing without combined vision and goals. This simulation confirmed that functional strategies are interlinked and require jointly coordinated formulation.

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System for green-field business and supply chain strategy integration

To analyse these findings, evaluation survey was designed and distributed along with the conceptual diagrams (Figure 4 and Figure 5).

The evaluation survey confirmed that the documented vision is not a true representation of the green-field concept and to identify the individual participant goals; specific questions were built into questionnaires related to the integrated strategy architecture.

These findings contributed to the process of characterising green-field integration and concluded that when multiple companies are integrated in formulating a green-field strategy, the vision and goals must be articulated in a method that the strategic vision is determined through the integrated goals and the goals should be representative of the integrated vision (Figure 8).

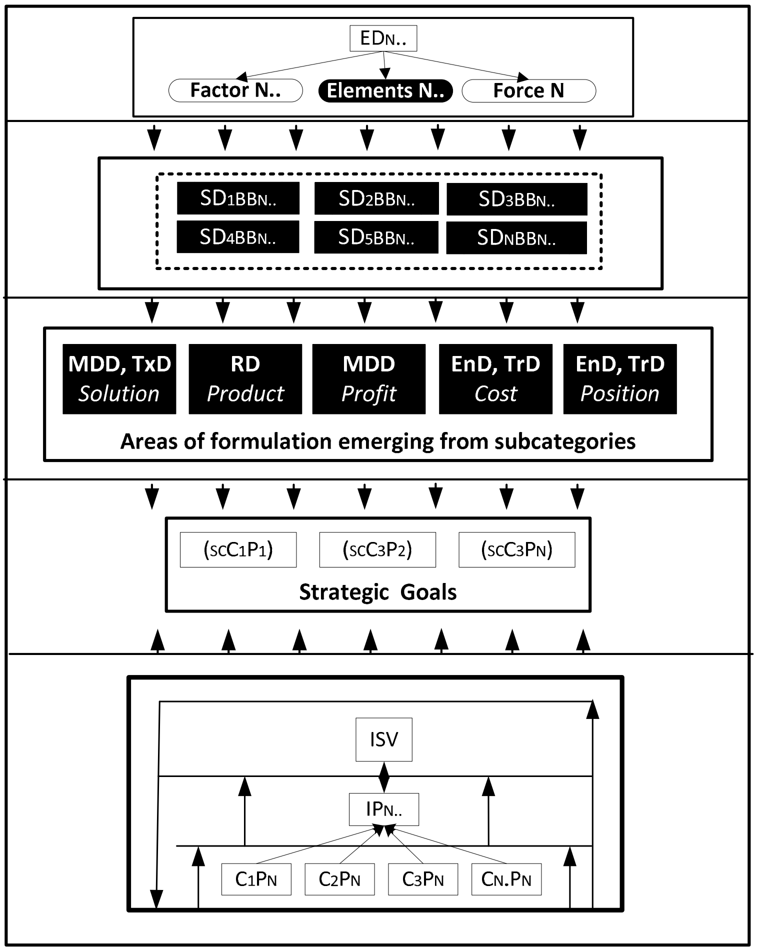

Figure 8: System for integrating green-field business and supply chain strategy

To confirm these findings, the evaluation survey and the integration questionnaire have proven detrimental in confirming the vision and goals validity, but also, to identify how the participants' goals can be grouped into categories that would serve as a link to the supply chain activities. Without identifying the individual goals, it would be impossible to ensure that the research is investigating the appropriate concepts, which is crucial for capturing the essence and forecasting the effect of supply chain integration.

Conclusion

This paper derived a new understanding of the process of architecting green-field integration strategy. The literature review derived insights into the shortcomings of the methods present in existing literature. The process of addressing these gaps identified in existing literature, facilitated the redefining the existing understanding of the problems conceiving the relationships between business and supply chain strategy.

The theory building process applied the case study research method and confirmed that there are critical problems present in professional practice in the context of visualising green-field integration.

This paper reviewed the segments of strategy architecture that have been somehow overlooked, such as how strategy is designed on a green-field project level involving integration of a number of companies that operate in diverse fields.

The findings from this paper can be applied as guidance for academics and practitioners in green-field integration process. The paper also outlined a new approach for progression into accepting reality in the strategy architecture process. The supply chain participants were selected based on that acceptance of reality and the need for integrating the business vision.

This paper brought new understanding and confirmed that corporate strategy represents a vision that serves as a central idea but it emerges from the business objectives and is articulated through evaluating the operational capabilities and the operational strategies. This differentiates the understanding from existing methods for architecting the relationships between the business and supply chain strategy.

Existing methods discussed in the literature review proposed a formulation of a business strategy representative of vision and goals that can only be evaluated as desired status or action objectives. Such architecture signifies a vision that requires accomplishment of ambitious action objectives that can only be accomplished through the operational activities. Setting up ambitious action objectives without considering the assets, logistics capabilities, transportation infrastructure, know-how, and culture, will inevitably result with formulation that contains desired and unrealistic vision and action objectives.

This research is part of research paper series related to this topic (Nicolescu, Huth, Radanliev, & De Roure, 2018b; Nurse, Radanliev, Creese, & De Roure, 2018; P. Radanliev et al., 2018; P. Radanliev, De Roure, Nicolescu, & Huth, 2019; P Radanliev et al., 2018; Petar Radanliev, 2019a, 2019b, 2014, 2015a, 2015c, 2015b, 2016; Petar Radanliev et al., 2019; Petar Radanliev, Charles De Roure, Nurse, Burnap, & Montalvo, 2019; Petar Radanliev et al., 2019, 2018, 2019, 2019, 2019, 2019, 2019, 2019, 2019; Petar Radanliev, Rowlands, & Thomas, 2014; Petar Radanliev, De Roure, Nurse, Montalvo, & Burnap, 2019a, 2019b; Petar Radanliev, De Roure, Cannady, et al., 2019)(Nicolescu, Huth, Radanliev, & De Roure, 2018a; Petar Radanliev, De Roure, Nurse, Rafael, & Burnap, 2019; Petar Radanliev et al., 2019, 2019; Taylor, P., Allpress, S., Carr, M., Lupu, E., Norton, J., Smith et al., 2018).

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