

Hypothesis

Challenges in Determining the Scope of Rail Megaprojects: Responding to Ever-Increasing Infrastructure Demand

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Abstract: While megaprojects can be defined as highly complex, time-consuming, and cost-intensive endeavors, for rail infrastructures they are even more problematic. As a starting point, for rail megaprojects, their scope may, at times, alter due to some risks and uncertainties. As many such projects exceed many years in development, their scope and formation will not be a linear trajectory. It is, therefore, the aim of this paper to evaluate the difficulties in determining the scope of rail megaprojects. This paper first introduces the theoretical framework via adaptive decision-making and policy setting when dealing with mega rail projects. Through sustainable development, carefully applied research is undertaken to highlight some of the key shortfalls of current practices when dealing with mega rail projects. This includes categorizing sustainability into four dimensions: social, economic, environmental, and engineering for rail infrastructure. To address the existing gap in the literature, including the appropriate alignment of policy planning and design, this paper will carefully review the complex science of rail megaprojects. This can be seen as a conceptual framework, which combines complex theory and practice to develop a theoretical perspective to initiate, plan, execute, and commission mega rail projects. Particularly with an international focus, this paper will review global development, targeting rail infrastructures. For rail megaprojects, strategically integrated objectives are traditionally key functions within the regional land transport network along with the national network and are necessary to (i) improve connectivity, both nationally and inter-regionally for people, communities, regions, and industry via effectively linking the existing broad-based transport network; (ii) enhance logistical systems and trade; (iii) provide a consistent framework for continuous sustainable development; and (iv) provide a consistent framework for long-term economic and social benefits.

Keywords: rail megaprojects; complex megaprojects; sustainable development



Citation: Gharehbaghi, K.; Tee, K.F.; McManus, K. Challenges in Determining the Scope of Rail Megaprojects: Responding to Ever-Increasing Infrastructure Demand. *CivilEng* **2023**, *4*, 538–550. <https://doi.org/10.3390/civileng4020031>

Academic Editors: Angelo Luongo and Francesco D'Annibale

Received: 25 February 2023

Revised: 29 March 2023

Accepted: 24 April 2023

Published: 8 May 2023



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1. Introduction

Infrastructure, in general terms, can be defined as a network of assets ranging from services, resources, etc. [1–3]. This collection of assets then acts as one system for one or more specific purposes. Further such systems, as a whole, are intended to be maintained indefinitely, and subject to ongoing and continuous replacement and refurbishment of their components [4,5]. Generally, infrastructure can be split into two different categories: (a) hard, which includes, water, gas, electricity, waste, and transport provision (roads, rail, air); and (b) soft, which provides actions and support via strategies and plans [6–10]. Both categories support communities while encouraging various economic, social, and environmental activists to respond to current and future needs. Further, hard infrastructure could

be typically categorized into civil and non-civil infrastructure. While civil infrastructures consist of roads, bridges, pipelines, etc., non-civil infrastructures consist of IT systems, etc.

Most of all, infrastructure is an important major investment in developed or developing countries [11–13]. Subsequently, infrastructure comprises the assets that provide people with access to economic and social facilities and services, such as roads, water supply, wastewater, power supply, telecommunications, etc. [14,15]. It also includes buildings, other construction infrastructure, plants, and equipment.

Moreover, rail megaprojects possess a very diverse range of complexities [16,17]. They further noted that this complexity ranges from both short-term and long-term scenarios. One such complexity is the inclusion of sustainability, particularly during the project initiation stage. Sustainability can be defined as maintainable strategies that consider the environmental, economic, social, and technical aspects of a project [17]. According to [18] sustainability does not just include the role of transport, but also cities that successfully integrate commerce, culture, and science, leading to improved productivity in social, human, and economic development. Further, sustainability, although not a new concept, is an integral part of any infrastructure planning and development. An overview of infrastructure planning and development is shown in Figure 1.

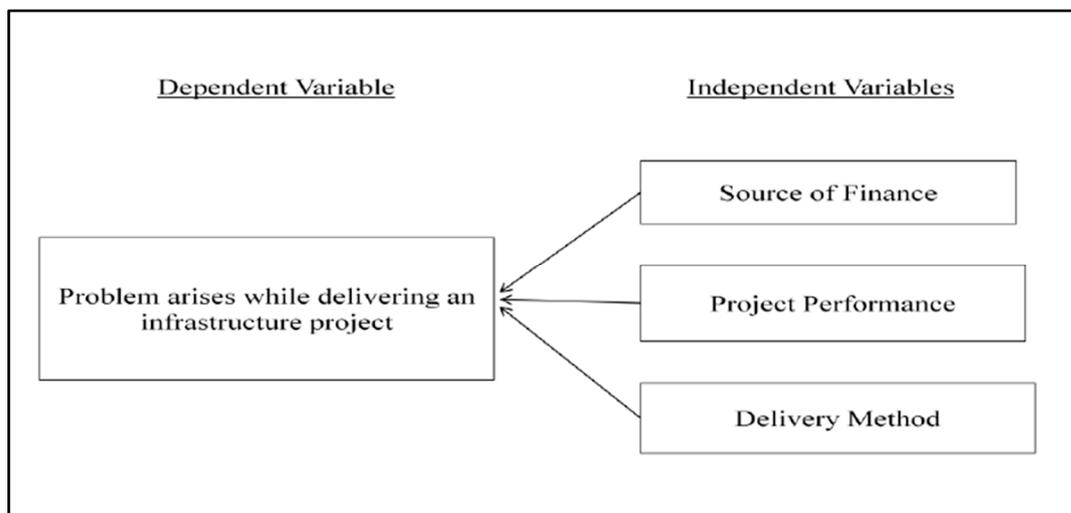


Figure 1. An overview of infrastructure planning and development.

As can be noted, infrastructure planning and development consists of dependent (main) and independent (sub-group) variables. Such sustainable development thinking encompasses the realignment of better living conditions through: sustainable cities; green buildings; sustainable agriculture; innovative technologies to improve living standards; and more balanced lifestyle modification.

Aim of This Paper

This article aims to carefully assess the key challenges in determining the scope of rail megaprojects. In this light, it is intended to successfully respond to ever-increasing demands on such infrastructure. Thus, resolving the challenges of sustainable development for rail megaprojects. As noted by [19–21] among others, reacting to the challenge of sustainable development will require dedicated collective action at many levels. The existing infrastructure is barely adequate to meet current needs, let alone future needs. Making cities more sustainable is a fundamental module of that response. Undoubtedly there is a requirement to substantially transform cities to respond to ever-increasing infrastructure demand. Failure to recognize the complex emerging trends that will shape cities threatens to undermine the robustness of public and private investment and is a significant planning risk. Consequently, there is real potential to invest precious public funds in infrastructure that will have limited future adaptability, usefulness, and hence sustainability. As

a fundamental part of this process, meeting growing demands for investment in public infrastructure and services when the revenue base is declining is a key issue.

2. Complex Megaprojects

Through an extensive literature investigation, it is noted that there are countless definitions of megaprojects. An example of a megaproject overview is shown in Figure 2.

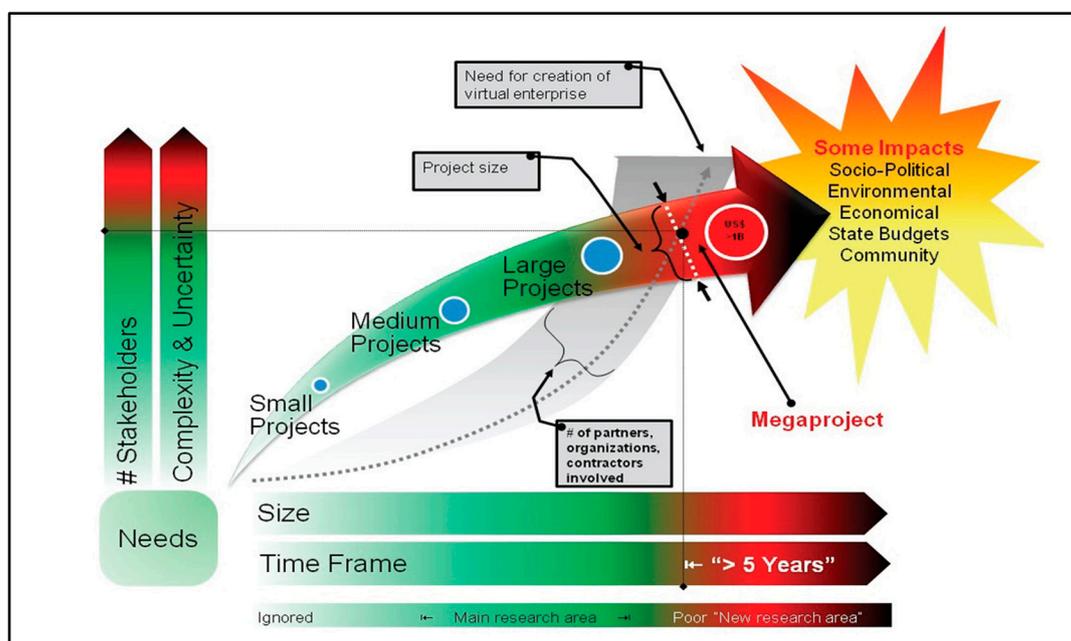


Figure 2. Megaprojects among projects [22].

Generally, megaprojects can be defined as multifaceted, complicated, and convoluted projects which are time-consuming, costly, vastly complex and that have a high impact on society, the economy, and the environment [23,24]. All of this can indicate high factors too. Some examples of megaprojects include mega transportation projects, such as mega metro projects. Many authors, including: [25–31] and others, argue that megaprojects have been important in the significant increase in quality of life (in terms of health, safety, economic opportunity, and leisure time and activities) and economic performance. Therefore, it can be said megaprojects are not only important to increase economic performance, but also social performance within cities, states, and countries. The involved investment can lift economic growth and support social objectives. Further, health, education, and efficient water sanitation services help lay the groundwork for a more productive and healthy population capable of contributing to sustained economic growth [32–36]. However, megaprojects are complicated and thus require responsive strategies. To deal with the complexity of megaprojects, new methods, and techniques, such as adaptive, iterative, and agile, are emerging [37–43]. Figure 3 shows an overview of the complexity of megaprojects.

As can be noted, the complexity of megaprojects includes a broad range of steps in different areas of complexity philosophy. Subsequently, in dealing with a megaproject, critical thinking and rationale are needed that deal with:

- Complexity thinking, which is the conduct of economics, business, and even politics.
- Complexity theory, which is based on relationships, emergence, patterns, and iterations. It maintains that the universe is full of systems (e.g., weather systems, immune systems, and social systems) that are complex and are constantly adapting to their environment, hence the term complex adaptive systems.

- Complex adaptive systems are a specific type of complex system. These systems are complex in that they are diverse and comprise multiple interconnected elements; they are adaptive in that they can change and learn from experience.

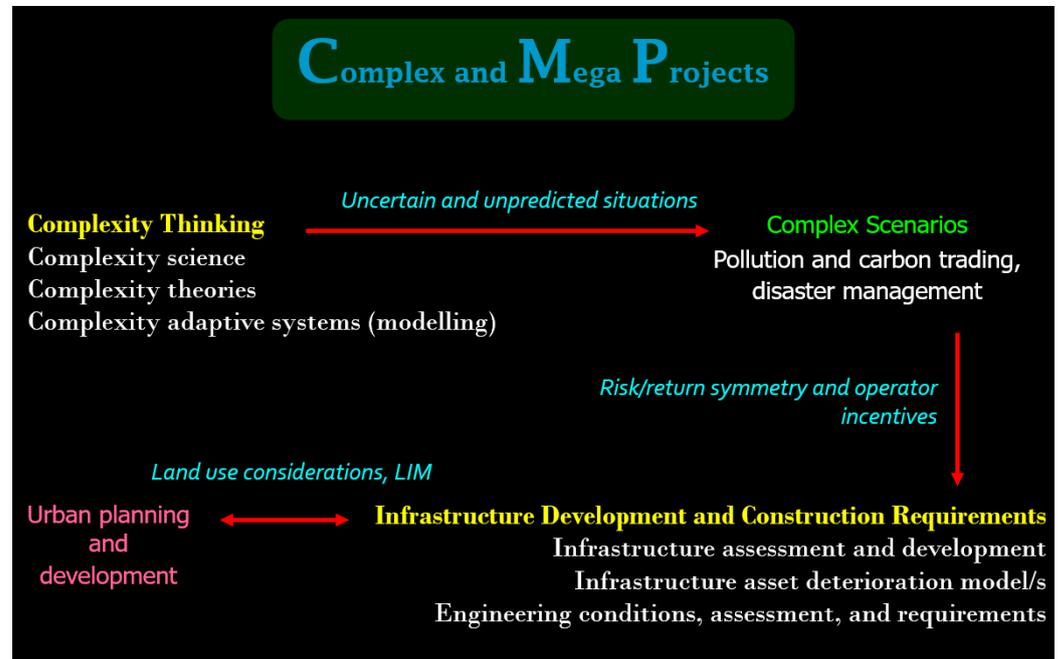


Figure 3. An overview of complexity in megaprojects.

The above considerations are part of the science of complexity thinking. The science of complexity is the result of a multi-disciplinary approach, a large number of influential stakeholders, and, of course, the degree of uncertainty. The multi-disciplinary approach consists of economic considerations and urban development requirements, among others. Predominantly for urban development, careful planning is required, such as land use considerations (e.g., zoning, etc.) and Land Information Modelling (LIM). LIM and other planning strategies are valuable for infrastructure development such as mega rail projects and their construction requirements.

Mega Rail Projects

Megaprojects can be defined as highly complex, time-consuming, and cost-intensive endeavors. Moreover, mega rail projects can be defined as endeavors that are not only highly complex but also time-consuming and costly undertakings [44–49]. For rail infrastructure, such concerns are even more problematic. Mega rail projects are complicated, especially in terms of genuine long-term private sector equity commitment [50]. This requires a long-term commitment from the private sector which will provide the expertise and know-how for such complex and large projects. The term typically refers to the technical structures that support a society, such as roads, water supply, sewers, electrical grids, telecommunications, and so forth. For mega rail projects, while the development phase is essential, they can fail during this phase if key stakeholders are not correctly aligned during the planning stage. An example of key stakeholders' alignment is shown in Figure 4.

As noted in Figure 4, the key stakeholders of mega rail projects include all the relevant bodies at national and local levels as influential stakeholders. Both government and non-government organizations which deliver auxiliary services such as roads, planning requirements, etc. are included. As organizations have indirect relationships with mega rail infrastructures, they also need to be involved during the life of such projects. Further, for mega rail projects, there are central infrastructure development and engineering factors including:

- Sustainability, including social, environmental, and economic focuses such as key cost drivers, etc. Moreover, sustainable urban development would also be included in this factor.
- Innovative engineering, featuring state-of-the-art design and application of rail infrastructure components, including structural, electrical, intelligence systems, etc.
- Government regulations and guidelines, which not only support prolonged development but also ensure a high level of livability for the communities.

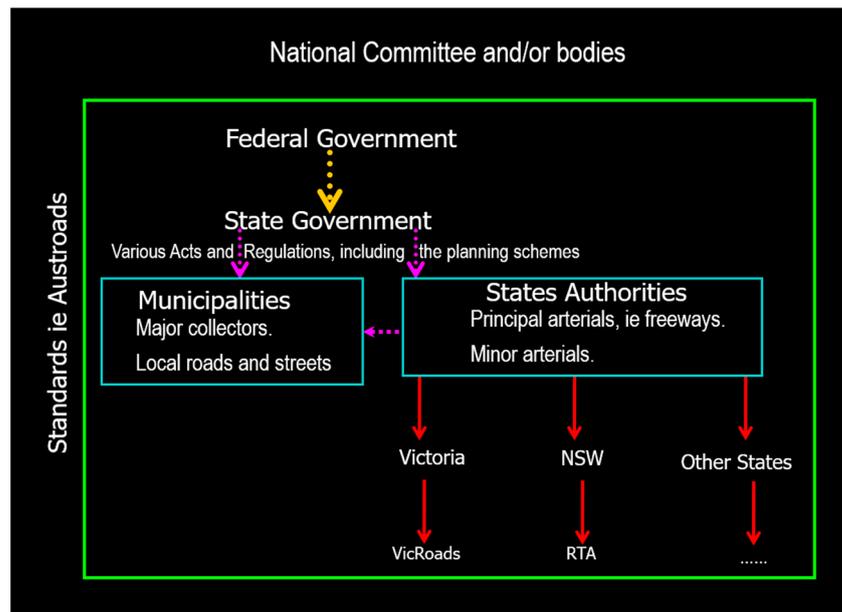


Figure 4. Key stakeholders’ alignment.

Nonetheless, a successful key in effective urban development is appropriate stakeholder alignment that needs to carefully integrate through sustainable progress. An important part of this is the inclusion of the “triple bottom line” (TBL). TBL encapsulates sustainability’s three central pillars, environmental, social, and economic progress. TBL thus provides a framework to assess sustainability. TBL is shown in Figure 5.

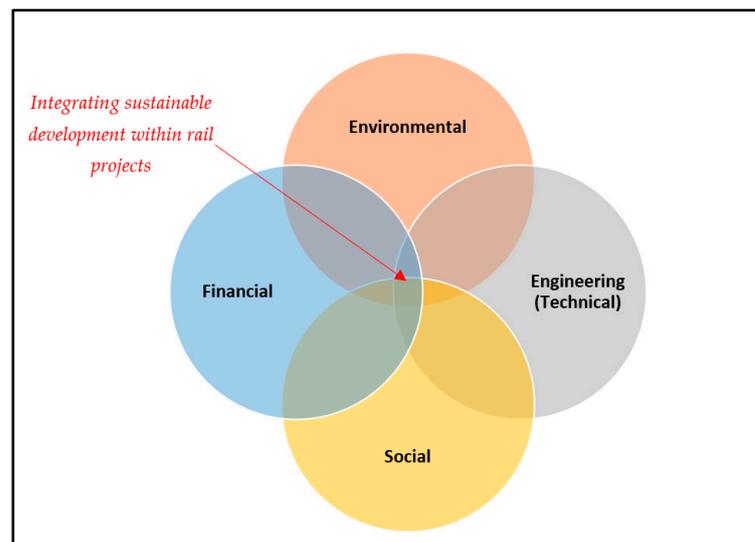


Figure 5. The inclusion of engineering factors with the usual triple bottom-line factors.

For mega rail projects, cost and time overruns are common [50]. This is due to the complex nature of such projects when integrating sustainable development within rail projects. Furthermore, the difficulty of engineering factors when meeting sustainable development [51,52]. Therefore, the engineering pillar needs to be separated from the usual triple bottom-line factors, as shown in Figure 5. For rail megaprojects, effective urban development deals with careful strategic positioning. This strategic positioning needs to be concurrently prepared within the scope setting of such projects.

3. Scope of Rail Megaprojects

Rail megaprojects attract a high level of both public and political interest due to their cost and their impact on the environment, economy, and ecology [53]. These rail megaprojects are risky due to long planning durations and inherent complex interfaces [54,55]. The scale, duration, cost, and risk exposure of rail megaprojects have grown drastically over time. Time and cost considerations are critical elements in the evaluation of rail megaprojects. Furthermore, megaprojects often have many factors influencing their performance, but time and cost risks are the most frequent megaproject risk [56]. With the increasing number of large railway infrastructure megaprojects around the world, the performance of these projects has always been associated with delays, cost overspending, or shortcomings in quality [57]. Overrun is a common problem in public and private-sector rail megaprojects [58]. Overruns have stayed high and constant for the past decades. Reporting of time and cost overruns is frequently based on limited, or misreported, data. Cost overruns in megaprojects should be evaluated by capturing the detailed contextual knowledge of the megaprojects and avoiding the simplistic approach of deducting the initial and final costs and labeling the differences as ‘over budget’.

All countries suffer from overrunning with no improvement over time. Nine out of ten rail megaprojects have cost and duration overruns. Overruns of up to 50% are common, and over 50% are not uncommon; for example, the cost overrun for the Channel Tunnel was 80% [38]. Cost is just one element of a megaproject, and megaprojects warrant more holistic considerations, including acknowledgment of other significant characteristics, such as their embodiment of large components of risk, political influences, organizational pressures, and management complexities [21]. There are many cases of megaproject failures with planning, procurement, construction, and operation of rail megaprojects which lead to time and cost overruns. However, there are also positive and successful cases. The criteria for success or failure have to be defined appropriately because the widely used time and cost overruns are only rough indicators. Leadership effectiveness, project team, cost management, communication, time management, quality management, risk management, and stakeholder participation, respectively, are found to be critical factors to the project’s success. Thus, it is recommended that the participation of relevant stakeholders is very essential for the successful completion of projects. The evaluation has to be extended to allow for an integrated assessment of all sustainability aspects. Coping with uncertainty is a crucial issue, such that risk and change management is an essential requirements for a successful planning and implementation process [18].

Particularly the link between corruption and poor quality of the scope of megaprojects delivered needs to be carefully investigated [41]. Countries with higher corruption tend to have worse infrastructure. Corruption can be a factor in megaproject failure, especially in highly corrupt countries. It cannot quantitatively relate exactly the impact of corruption on a megaproject’s poor performance, mainly because corruption is often considered a phenomenon more associated with individuals than with projects. Future research activities should deepen the correlation between corruption and project performances, and isolate corruption from other factors that may lead megaprojects to failure [19].

Korea constructed a high-speed railway called Korea Train eXpress (KTX) in 2004. Numerous challenges during construction resulted in cost overruns and schedule delays. The critical factors for the poor performance of the KTX project came from the complex nature of large-scale construction rail megaprojects. It is important to develop a time-cost

analysis of project delay, identify and mitigate the risks, and quantify the impact of social and political risks for rail megaprojects. With lessons learned from the KTX project, one can better identify critical causes of schedule delays and cost overruns for evaluating rail megaproject performance [44].

A researcher prudently assessed the critical success factors and challenges of the railway megaproject in Ethiopia [29]. In Ethiopia, some problems resulted in delay, poor quality, and cost overrun due to the absence of qualified staff, offensive and poor attitude toward project management work, and inadequate facilities, and equipment. The study also concluded that the major challenging failure factors were investment cost, skilled manpower in the sector, project integration and stakeholder management, contract administration, and land topography. The Ethiopian Railway Corporation should emphasize improving contract administration practices, integrating project activities, and improving project quality management activities.

Likewise, a researcher states, “The following interesting questions are not addressed in the present paper, because they have been covered elsewhere: Why urban rail projects differ from other projects, the causes of cost underestimation and demand overestimation, possible differences between public and private projects, and how risk assessment and management may be designed in practice”, ([54], p. 4). The main reason why the rail megaprojects are generally completed over time and the budget is due to their complex nature. This notion is also supported by various authors including [18,25,45,46,55].

As discussed in [11], mega rail projects have significant complexity due to their extensive project life cycle (project initiation to finalization stage). Further, they noted that their project duration is also extensive, with many projects exceeding 5 years in duration. Along with the use of innovative techniques, technologies, etc., all will thus create a high level of uncertainty. Hence why, when such projects are completed, they are usually over budget and time. These are the factors of complexity in mega rail projects. Nonetheless, every effort is made to ensure that such projects are well-planned during the project conception. One key task of this exhaustive planning is a methodical determination of the rail project’s scope. Figure 6 provides an overview of the scope of megaprojects.

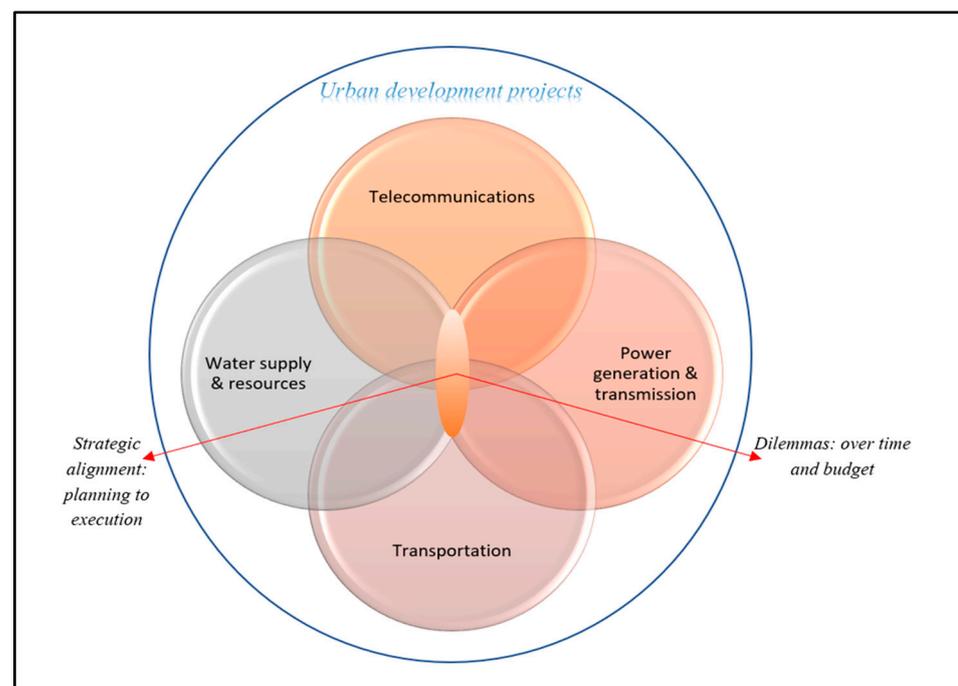


Figure 6. An overview of the scope of megaprojects.

As noted in Figure 6, rail megaprojects possess dilemmas, such as overtime and budget, along with difficulty in planning to execution (strategic alignment). As already noted,

megaprojects are multifaceted, complicated, and possess a high level of complexity. One of the most challenging aspects of rail megaprojects is the complexity of their techniques and method of design [40]. Thus, the containment of rail megaprojects goes beyond the normal understanding of significant/extreme cost and duration. Innovation and technological advancements (methods or techniques, etc.) are also additional considerations of mega transportation infrastructure. For example, tunnel boring and construction (under-functioning cities) is a very difficult and risky issue. Further, such projects possess not only high innovation but also multifaceted processes, such as national-end intercity traffic control systems. These processes could also include pioneering information technology systems that align with specific government financial/fiscal schemes. All in all, the confinement of cost and duration goes along with innovation and technological advancements.

Moreover, the challenges in determining the scope of rail megaprojects are further complicated by the inclusion of their overall configuration with various urban development projects—strategically integrated megaprojects (shown in Figure 7).

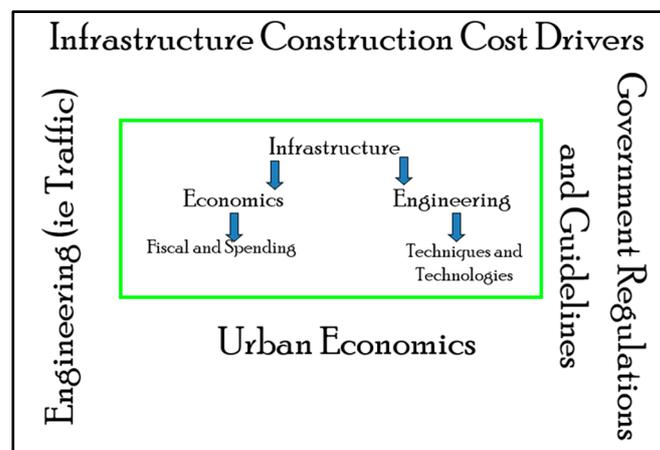


Figure 7. Strategically integrated rail megaprojects.

Urban development can be defined as the expansion into rural and natural areas such as forests, marshlands, etc. [8]. As populations grow, a need for more houses for people to live in develops. This is what causes urban development. As the demand for housing increases, cities begin to expand into new areas. Urban economics is broadly the 'economical study of urban areas; as such, public transit, housing, and local government finance'. So, therefore, urban economics concentrates on the allocation of resources across space in urban areas. Urban economics can be divided into six related themes [19,22,48]:

1. Market forces in the development of cities—how the location decision of firms and households causes the development of cities.
2. Land use within cities—identifying land-use controls, such as zoning, and interpreting how such controls affect the urban economy.
3. Urban transportation—proposed transportation developments such as light rail.
4. Urban problems and public policy—poverty or crime, to economics by seeking to answer questions with economic guidance.
5. Housing and public policy—funding, uncertainty, space, etc.
6. Local government expenditures and taxes—i.e., the council's annual Rate Spending Composition (RSC).

As already noted, one of the central dimensions of rail megaprojects is the inclusion of sustainable development. For rail megaprojects, this is based on the careful alignment of urban development projects vs. transport-driven projects—strategically integrated rail megaprojects (shown in Figure 8).

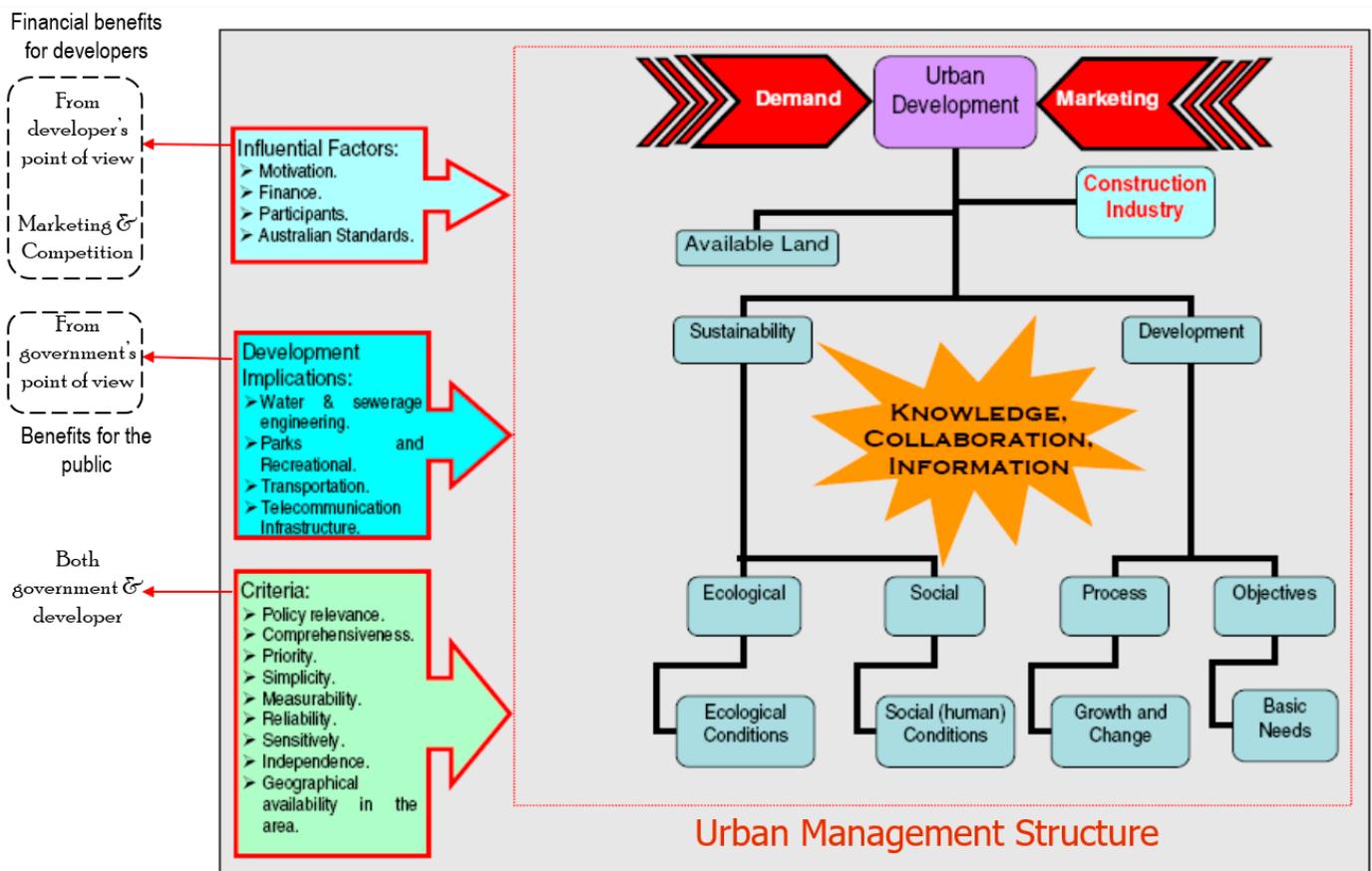


Figure 8. Conceptual framework—strategically integrated rail megaprojects.

For rail megaprojects, strategic integration considers the three pillars of sustainability, social, economic, and environmental integration. There are three areas of direct impact: influential factors such as finance; development implications such as adequate infrastructure; and criteria in terms of specific KPIs, such as priority, reliability, and so on. These direct impacts are based on all the key stakeholders, including governments. Generally, governments have a clear strategy for rail megaprojects which also addresses both livability and development. This also examines the rail megaproject development and the larger impact on pollution and natural resources. Subsequently, specific environmental regulations and procedures such as Environmental Impact Assessment (EIA) are utilized. Such regulations ensure that attention is given primarily to maintaining ecosystem functions, life support systems, and representative forms of all other living natural assets. To ensure that rail megaprojects satisfy the appropriate environmental regulations and policies, the EIA, along with sustainability measures, are carried out. This is done to balance social, environmental, and economic objectives. For cities, this integration also requires a land management strategy that facilitates the market and protects land and cultural resources. Further, the alignment of urbanization and urban land-use decisions are critical determinants of strategically integrated rail megaprojects.

One of the greatest challenges for rapidly growing cities is to balance urban and rural development while vindicating environmental protection. This requires an integration of urban and rural land management strategies designed to: (I) better coordinate for planning and funding of land transport investments; (II) encourage private sector investment by encouraging easier policies; and (III) develop holistic land use and transport planning through better integration of technological advances.

In developed countries, where cities are growing at unprecedented rates, distorted land markets and ineffective urban land management have resulted in the degradation of environmentally fragile land; the occupation of hazard-prone areas; and the loss of

cultural resources, open space, and prime agricultural land. Thus, despite the deficiencies in government interventions in urban land markets, some degree of government control should be exerted over urban land use and development. Importantly, without effective rail infrastructure policies and regulations, private actors in the land market are unlikely to consider the costs that their decisions concerning the use, density, design, location, and timing of development may impose on sensitive land and cultural resources. For rail megaprojects, strategically integrated objectives are traditionally key functions within the regional land transport network, along with the national network, and are necessary to:

- Improve connectivity, both nationally and inter-regionally for people, communities, regions, and industry via effectively linking the existing broad-based transport network.
- Enhance logistical systems and trade.
- Provide a consistent framework for continuous sustainable development.
- Provide a consistent framework to provide long-term economic and social benefits.

Furthermore, strategically integrated rail megaprojects also need to consider the impact of growth and the need to provide the most accessible transportation networks for the various central business districts (CDBs) throughout cities. This alignment is generally based on various planning schemes at both state and local levels. For rail megaprojects, there is a need to address the effects of the state-controlled rail network features, including the sustainability impact such as noise, vibration, emissions, etc. Subsequently, effective urban development policies are necessary due to growth, demand, and other related issues. Typically, strategically integrated rail developments have a span of approximately 25 years or so for planning. For rail megaprojects, this long-term planning particularly needs to consider: (I) clear risk allocation (risk/return symmetry and operator incentives); (II) deal certainty (finance and economic objectives), and governmental inputs at all levels, including local; (III) the life-cycle cost streams for infrastructure analysis; and (IV) urban re-planning and redevelopment requirements, such as re-zoning and so on.

4. Concluding Remarks

While megaprojects are multifaceted, complicated, and convoluted; rail megaprojects possess dilemmas that require careful alignment to respond to difficulties, such as overtime and over budget, as well as difficulties from planning to execution. One of the most challenging aspects of rail megaprojects is the complexity of their techniques and method of design. Such complexity can lead to uncertainty and thus increase the estimated project costs and duration. Although not wanted, increased project cost and duration is a common factors when dealing with transportation megaprojects.

Consequently, the containment of rail megaprojects goes beyond the normal understanding of significant/extreme cost and duration. Innovation and technological advancements are also key considerations of mega transportation infrastructure and can subsequently reduce the project cost and duration. Furthermore, one way of overcoming many challenges (such as time and duration) of rail megaprojects is effective strategic alignment, to not only overcome the many obstacles of such projects but also ensure continuous sustainable development. As discussed in this paper, strategically integrated rail megaprojects align with both short-term and long-term project goals. For rail megaprojects, this may include major overhauls of rail networks, consolidations of better governmental involvement, and partnerships. Therefore, strategically integrated rail megaprojects can improve stakeholder collaboration and thus leading to improved project efficiency, productivity, and consistency.

Author Contributions: Conceptualization, K.G.; methodology, K.G., K.F.T. and K.M.; software, K.G.; validation, K.G., K.F.T. and K.M.; formal analysis, K.G., K.F.T. and K.M.; investigation, K.G., K.F.T. and K.M.; resources, K.G., K.F.T. and K.M.; data curation, K.G., K.F.T. and K.M.; writing—original draft preparation, K.G., K.F.T. and K.M.; writing—review and editing, K.G., K.F.T. and K.M.; visualization, K.G., K.F.T. and K.M.; supervision, K.G., K.F.T. and K.M.; project administration, K.G., K.F.T. and K.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The supporting data are attainable upon request.

Conflicts of Interest: The authors declare no conflict of interest.

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