

Urban Transformation Pathways for Green Sustainable Development: A DEMATEL Perspective from Datong

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ABSTRACT:

Within the framework of the global low-carbon transition, the systemic pathways of green transformation in resource-dependent cities have become a more critical issue to understand. Using Datong as an example, this paper integrates the “Decision-Making Trial and Evaluation Laboratory (DEMATEL)” and “Interpretive Structural Modeling (ISM)” to analyze the causal relationship and hierarchical order of fifteen major factors that affect urban transformation.” The findings indicate a three-level mechanism comprising of a root driving layer, an execution-transition layer, and an outcome layer. The core drivers of transformation are policy coherence and enforcement (A1), green investment intensity (B1), and industrial diversification with low-carbon upgrading (B2). The execution-transition layer (A2), monitoring and data capability (A3), just transition financing (B3), and enhancements in renewable energy penetration, end-use electrification, and green mobility infrastructure (C1–C3) are the links between strategic intent and actual outcomes. The outcome-oriented factors that reflect transformation performance are environmental quality improvement, ecological restoration, carbon-intensity reduction, employment resettlement, energy affordability, and public satisfaction (D1–D3, E1–E3). The paper offers a systematic analytical framework of the driving forces of sustainable transition in resource-based cities and presents policy-relevant implications of advancing the green development of Datong.

Keywords: Green sustainable transformation; Resource-based cities; DEMATEL–ISM; Policy coherence and enforcement; Industrial diversification and low-carbon upgrading

1. Introduction

Green and sustainable development has become an urgent issue for resource-dependent cities worldwide. Under tightening global climate commitments and the structural decline of fossil-fuel-based growth models, coal cities face not only environmental pressures but also challenges related to social equity, employment restructuring, and economic diversification. Compared with many coal cities in Europe, Australia, or other parts of China, Datong exhibits a more deeply entrenched dependence on coal extraction in terms of industrial structure, fiscal revenues, and labor market composition. This makes its transition more complex, involving simultaneous demands for ecological restoration, livelihood protection, and economic restructuring. As a representative coal-based city undergoing large-scale transformation, Datong provides an important case through which the mechanisms linking climate policy, social equity, and

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economic restructuring can be examined. Understanding these mechanisms is essential for helping deeply resource-dependent cities overcome structural lock-in and achieve sustainable transformation.

The process of urban transformation is multidimensional and influenced by institutional, economic, technological, environmental, and social factors. The existing literature emphasizes the importance of regular policy implementation, green investment, industrial modernization, the use of renewable energy, ecological rehabilitation, and social security. However, the interrelations between these factors are not researched in detail. When dealing with resource-based cities, where path dependence and structural constraints are strong, it is necessary to establish the interaction between the two to establish effective transformation pathways.

The paper applies “Decision-Making Trial and Evaluation Laboratory (DEMATEL) method to demonstrate the” fundamental and strength of influence of fifteen significant factors around the transformation of Datong. Based on these findings, Interpretive Structural Modeling (ISM) is applied to create a hierarchical framework that separates root drivers, execution and transition mechanisms, and outcome-oriented indicators. This combined DEMATEL-ISM model offers a methodological framework to comprehend how policy coherence and enforcement, green investment intensity, industrial diversification and low-carbon upgrading, renewable energy penetration, electrification, ecological restoration, and social well-being interact to determine the transition path of Datong.

The results help to better understand sustainable urban transition in resource-based cities and provide policy-relevant information on how to guide green development in complex systemic conditions.

1.1 Research Questions

Which factors serve as the fundamental drivers of green transformation in resource-based cities, and how do their causal relationships shape the overall transition process?”

How do institutional, economic, technological, and infrastructural elements function as intermediary mechanisms during the transformation? What bridging roles do they play between drivers and outcomes?

How are environmental improvements, ecological restoration, carbon-intensity reduction, and social well-being influenced by preceding factors, and what structural positions do these outcome-oriented elements occupy within the transformation system?

2.Literature Review

2.1 Key Research Areas and Interpretive Frameworks in the Transformation of Cities “Dependent on Natural Resources”

“The study of how resource-based cities change in a sustainable way has grown quickly, leading to several connected topics.”

(1)Urban transition performance and pathways

The first group of studies focuses on how coal-based and resource-based cities are changing over time. According to Tan *et al.*, an analysis “of 19 resource-based cities in Northeast China” shows that capital investment, transport systems, and good locations

strongly affect economic, social, and environmental outcomes. In contrast, policy support and labour have a smaller impact. Gu et al. provide a detailed review and data analysis of studies on “China’s resource-based cities from 2002 to 2022.” They highlight key topics such as resource decline, changes in industries, environmental stress, and system reforms, while also pointing out ongoing challenges in city governance and sustainability.

(2) Green development and low-carbon transition

“Expanding on this, a second strand is concerned with green and low-carbon transformation paths. Gong constructs a configuration-based model based on fuzzy-set qualitative comparative analysis (fsQCA) of 113 Chinese resource-based cities, finding several combinations of environmental regulation, industrial structure, innovation and factor endowment that can result in high-performance green transformation. Other articles examine spatial land-use and ecological patterns: Li et al. examine the construction land expansion and its drivers in Chinese resource-based cities, demonstrating the role of economic growth, population and policy in the formation of spatial patterns, and Zhang et al. examine green and sustainable land use in coal cities, demonstrating the impact of environmental regulation, public expenditure and trade on green land-use efficiency.”

(3). Case-based analyses of specific resource-based cities

“A third stream of literature resorts to case-based studies of cities and models of transformation. Xue et al. discuss the growth and development of Datong as a classic resource-based city, and how the spatial structure is transformed by coal depletion and planning interventions. The paper by Bendayana on Jiyuan examines how a small resource-based city can be re-packaged as a national sustainable development experimental zone by industrial diversification and institutional experimentation. The qualitative research on the coal transition in Datong also shows the social and cultural aspects of restructuring, such as labour displacement, community adaptation and new urban imaginaries. Collectively, these studies offer deep descriptive and analytical information, but they seldom formalise the internal causal structure between several drivers and outcomes.”

(4). Governance, policy interventions, and just transition

“A fourth body of research examines governance, policy and equitable transition. Wu et al. apply a multi-period difference-in-differences approach to examine the impact of national support policies on the environment in cities where mineral resources are almost exhausted. They discover that these policies can significantly reduce pollution but also transform local industries. Studies on carbon reduction indicate that green transformation in resource-based cities occurs via environmental regulations and low-carbon policies, which inform the manner in which money is invested and the decision-making process of industries. Recent research on strong and flexible development within the framework of dual-carbon objectives of China characterizes resource-based cities as systems that need to manage shocks, adapt, and expand. These works introduce the concept of resilience to transformation research and reinforce concepts such as clear policies, green investment, and social benefits such as jobs, affordable energy, and public satisfaction.”

(5). Applications of complex-systems methods (DEMATEL, ISM, etc.) in urban studies

“Lastly, a fast-growing methodological sub-literature applying DEMATEL, ISM and similar tools to analyze complex sustainability problems exists. Huang et al. determine

the influencing factors of urban resilience in China within the framework of 4R, and use a hybrid DEMATEL-ISM method to reveal the causal relationships and hierarchical processes between institutional, infrastructural and social factors. Makian *et al.* use DEMATEL-ISM to sustainable tourism in urban destinations, mapping the way key indicators create multi-level structures that inform policy priorities. Zhu *et al.* use fuzzy-DEMATEL to analyze the resilience of urban floods, which also proves the appropriateness of causal network techniques to socio-ecological systems. More recent studies of urban and community resilience apply DEMATEL in more general probabilistic or Bayesian models to model interdependencies between nodes in complex networks. These papers affirm that DEMATEL-ISM is highly appropriate to the analysis of multi-factor interactions and layered structures in sustainability transitions, yet it has been used mostly in the context of resilience, tourism or supply chains, and not resource-based urban transformation.”

(6) International perspectives on coal-city transitions

International studies on coal-city transitions offer important comparative insights. Research on Germany’s Ruhr region shows how long-term industrial lock-in and strong regional governance shaped a gradual shift from coal to services and technology (Grabher, 1993; Hospers, 2004). In Poland’s Upper Silesia, studies highlight the social and political challenges of phasing out coal under the EU’s Just Transition framework, particularly labour immobility and welfare dependence (Nowakowska *et al.*, 2021). Australian cases such as the Latrobe Valley emphasise community participation, worker retraining and investment planning as key components of a socially just transition (Edwards *et al.*, 2022). North American evidence from Appalachia shows how coal-based identity and weak diversification capacity create persistent structural lock-in (Bell & York, 2010). These international experiences reinforce the importance of governance capacity, social equity, and economic restructuring—elements that also underpin Datong’s transition and justify the relevance of analysing its internal causal mechanisms.

2.2 Vertical evolution: temporal and methodological developments

(1). Early phase: descriptive, policy-oriented studies

From a temporal perspective, the literature on resource-based city transformation has experienced a clear evolution. Early work in the 2000s and early 2010s tended to adopt descriptive and policy-oriented approaches, focusing on defining resource-based cities, documenting their socio-economic problems, and proposing normative transformation strategies. Reviews of mining cities and resource-based cities underline themes such as resource exhaustion, mono-industrial dependence and environmental degradation, but they seldom quantify multi-dimensional performance or reveal internal mechanisms. Around the mid-2010s, studies began to incorporate quantitative performance evaluation and spatial analysis.

(2). Mid phase: indicator systems, spatial analysis, performance evaluation

Tan *et al.* construct a composite index to measure urban transition performance in Northeast China, which covers social, economic and eco-environmental dimensions. Li *et al.* extend this line of work by analysing spatiotemporal patterns and drivers of construction property expansion in resource-based cities using GIS as well as econometric

models. Xue et al. apply remote sensing to trace the expansion and evolution of Datong, reflecting the increasing use of spatial data and long-term observations.

(3).Recent phase: complex-systems approaches, network analysis, configurational methods (e.g., fsQCA), and DEMATEL–ISM

With the rise of the “green transformation” agenda, Gong’s configuration-based study employs fsQCA to uncover multiple sufficient configurations rather than a single linear path, signalling a shift toward set-theoretic and configurational methods. Methodologically, there is also a clear movement from single-indicator or regression-based analysis toward complex-systems and network-oriented approaches. In sustainability and resilience research, DEMATEL and ISM have been increasingly used to capture causal feedbacks and hierarchical relations that conventional regression may overlook. Huang et al. explicitly integrate DEMATEL with ISM to derive a multi-level structure of urban resilience factors, while Makian et al. and Zhu et al. extend these tools to tourism sustainability and urban flood resilience, respectively. This methodological evolution reflects a growing recognition that urban transformation is governed by interdependent drivers, intermediate mechanisms and outcome indicators rather than isolated variables. However, despite these advances in both thematic scope and methodological sophistication, two gaps remain particularly salient for your study. First, resource-based city research has rarely combined a rich, multi-dimensional factor system with a DEMATEL–ISM framework that can explicitly distinguish root drivers, execution–transition mechanisms and outcome factors. Existing applications of DEMATEL–ISM mostly focus on resilience, tourism or specific infrastructure systems, rather than the comprehensive transformation of coal-based cities such as Datong. Second, although some studies discuss institutional drivers, green investment, industrial diversification, ecological restoration and social equity, they often treat these elements in parallel rather than modelling their causal ordering and layered structure. In this context, DEMATEL–ISM offers an advantage over purely qualitative institutional analysis because it can formalise the causal ordering and hierarchical structure of multiple interdependent drivers in a transparent and replicable way. While qualitative analyses can richly describe institutional and cultural dynamics, they often lack the ability to quantify interaction strengths or determine directional influence among factors. We acknowledge, however, that mixed-method approaches could further complement DEMATEL–ISM by capturing cultural, cognitive and community-level dimensions of transition that numerical scoring alone may overlook.

Although previous studies have examined the spatial evolution, industrial restructuring, environmental challenges, and policy interventions of resource-based cities, existing research remains fragmented and largely descriptive, lacking a systematic explanation of how institutional, economic, technological, environmental, and social factors interact to drive green urban transformation. Current studies treat these elements in parallel and seldom reveal their causal relationships or hierarchical structure, nor do they integrate them into a unified mechanism framework. To fill this gap, the current research uses an integrated DEMATEL-ISM model to Datong, determining the causal relationships between fifteen major factors and building a three-layer framework of root drivers, transition mechanisms, and sustainability outcomes, thus providing a holistic mechanism-based explanation of green transformation in resource-dependent cities.

3. Results and Discussion: DEMATEL–ISM Analysis of the Success Factors Shaping Datong’s Urban Transformation

To further examine the interrelationships among the different dimensions of influencing factors, this study applies an integrated DEMATEL–ISM approach to analyze the interactions among the 15 identified factors. The corresponding indicator codes are as follows:

Dimension	Code	Factor Name
A Governance and Institutions	A 1	Policy consistency and execution
	A 2	Cross-departmental/area collaboration
	A 3	Monitoring, Reporting, and Verification (MRV)
B Economy and Investment	B 1	Green investment intensity
	B 2	Industrial diversification and low <u>carbonization</u>
	B 3	Fair transition funding arrangements
C Technology and Infrastructure	C 1	Renewable Energy Penetration
	C 2	Terminal electrification and clean heating
	C 3	Green transportation and charging and swapping networks
D Environmental Performance	D 1	Air quality improved
	D 2	Ecological restoration and redevelopment of coal mining subsidence area
	D 3	Carbon intensity and energy intensity decreased
E Social and Justice Transformation	E 1	Reemployment and skill upgrading
	E 2	Energy affordability
	E 3 [”]	Public participation and satisfaction

Figure 1: Factor Codes for the Study of Success Factors in Datong’s Urban Transformation

Using an expert questionnaire survey, this study obtained pairwise influence scores for all factors and constructed the direct-influence matrix. To enhance transparency, the expert panel consisted of 15 individuals with professional backgrounds in urban planning, environmental management, local government administration, and low-carbon industry development, each with at least five years of domain experience. Their selection was based on professional relevance and familiarity with Datong’s transition policies, and the consistency of their scoring was checked through preliminary calibration discussions.

While expert scoring provides a structured means to quantify perceived causal relationships, we acknowledge that political, institutional, and industrial contexts may influence expert judgment. Future research could strengthen data reliability by incorporating stakeholder interviews or mixed-method approaches to capture broader community, industry, and governance perspectives that numerical scoring may not fully reflect.

Using an expert questionnaire survey, this study obtained pairwise influence scores for all factors and constructed the direct-influence matrix. Based on these data, a DEMATEL–ISM model was developed to analyze the success factors of Datong’s urban transformation. “The DEMATEL results were used to calculate the influence degree, dependence degree, centrality, and causality of the 15 factors and to generate the corresponding causal diagram.” “The ISM method was then applied to further derive the multi-level hierarchical structure. The specific procedures for model construction and analysis are illustrated in the figure below:

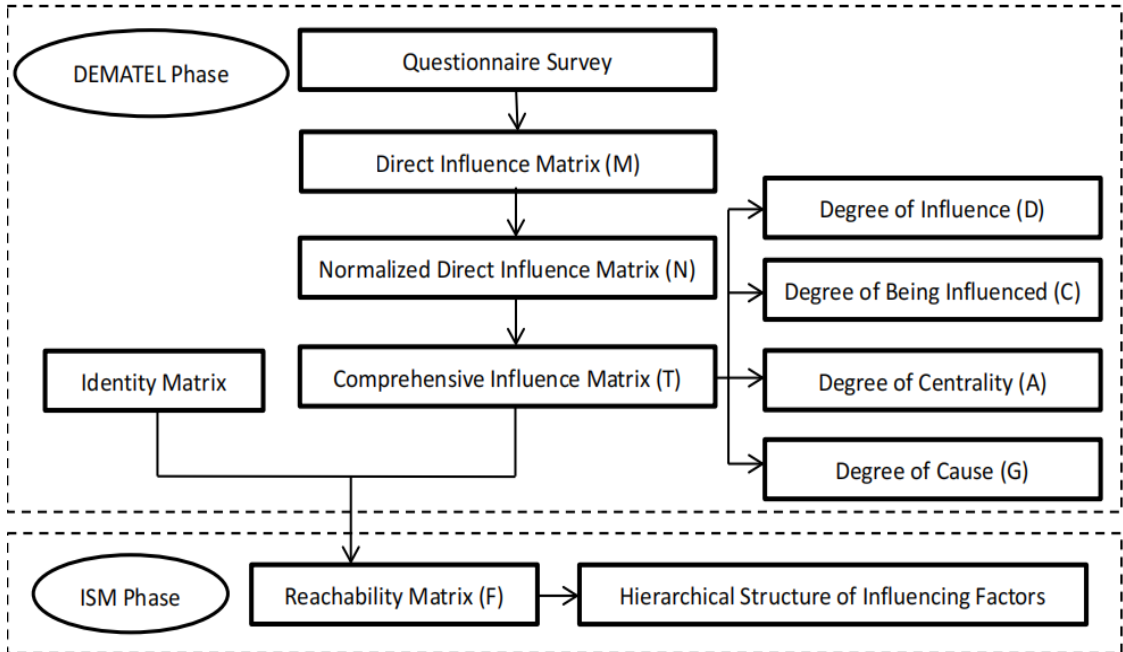


Figure 2. Model Construction and Solution Procedure

3.1 DEMATEL Analysis of the Success Factors in Datong’s Urban Transformation

(1) Construction of the Initial Direct-Influence Matrix

Fifteen professionals were called upon to rate the influence of each factor on the others.” “They applied a five-point “scale of 0 to 4, with 0 indicating no influence, 1 indicating minor influence, 2 indicating moderate influence, 3 indicating strong influence, and 4 indicating very strong influence.” Once all the answers were collected, the mean score of each pair of factors was computed and rounded off to the nearest whole number to minimize personal bias. These end values formed a 15 x 15 matrix of direct influences as illustrated below.

Factor	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	D3	E1	E2	E3
A1	0	2	3	1	0	4	4	4	2	2	2	2	2	1	1
A2	1	0	0	1	1	1	0	0	1	1	2	4	2	2	4
A3	0	1	0	1	1	1	0	0	1	3	2	2	2	3	2
B1	1	3	2	0	0	2	2	3	4	4	4	3	1	3	1
B2	1	3	3	0	0	2	4	1	2	2	4	3	2	3	4
B3	1	0	1	1	0	0	1	0	0	4	3	3	3	2	4
C1	1	1	1	0	1	0	0	1	1	1	4	2	4	3	2
C2	0	1	1	0	1	1	1	0	1	2	2	3	2	3	3
C3	1	0	1	0	1	1	1	1	0	4	3	4	2	2	2
D1	0	1	0	2	2	1	1	1	1	0	0	0	1	1	0
D2	2	1	1	1	2	0	0	0	1	1	0	0	1	1	1
D3	0	0	1	2	1	0	1	1	1	1	1	0	0	1	1
E1	0	0	1	1	1	0	1	2	1	1	1	0	0	1	1
E2	2	1	1	1	1	1	0	1	1	1	0	1	1	0	1
E3	0	2	0	1	0	1	1	1	1	1	1	1	1	1	0''

Figure 3. Direct-Influence Matrix

(2) Calculation of the Normalized Direct-Influence Matrix

The matrix of the direct-influence was normalized using the maximum row-sum method, producing the direct-influence matrix which is normalize

Factor	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	D3	E1	E2	E3
A1	0.0000	0.0588	0.0882	0.0294	0.0000	0.1176	0.1176	0.1176	0.0588	0.0588	0.0588	0.0588	0.0588	0.0294	0.0294
A2	0.0294	0.0000	0.0000	0.0294	0.0294	0.0294	0.0000	0.0000	0.0294	0.0294	0.0588	0.1176	0.0588	0.0588	0.1176
A3	0.0000	0.0294	0.0000	0.0294	0.0294	0.0294	0.0000	0.0000	0.0294	0.0882	0.0588	0.0588	0.0588	0.0882	0.0588
B1	0.0294	0.0882	0.0588	0.0000	0.0000	0.0588	0.0588	0.0882	0.1176	0.1176	0.1176	0.0882	0.0294	0.0882	0.0294
B2	0.0294	0.0882	0.0882	0.0000	0.0000	0.0588	0.1176	0.0294	0.0588	0.0588	0.1176	0.0882	0.0588	0.0882	0.1176
B3	0.0294	0.0000	0.0294	0.0294	0.0000	0.0000	0.0294	0.0000	0.0000	0.1176	0.0882	0.0882	0.0882	0.0588	0.1176
C1	0.0294	0.0294	0.0294	0.0000	0.0294	0.0000	0.0000	0.0294	0.0294	0.0294	0.1176	0.0588	0.1176	0.0882	0.0588
C2	0.0000	0.0294	0.0294	0.0000	0.0294	0.0294	0.0294	0.0000	0.0294	0.0588	0.0588	0.0882	0.0588	0.0882	0.0882
C3	0.0294	0.0000	0.0294	0.0000	0.0294	0.0294	0.0294	0.0294	0.0000	0.1176	0.0882	0.1176	0.0588	0.0588	0.0588
D1	0.0000	0.0294	0.0000	0.0588	0.0588	0.0294	0.0294	0.0294	0.0294	0.0000	0.0000	0.0000	0.0294	0.0294	0.0000
D2	0.0588	0.0294	0.0294	0.0294	0.0588	0.0000	0.0000	0.0000	0.0294	0.0294	0.0000	0.0000	0.0294	0.0294	0.0294
D3	0.0000	0.0000	0.0294	0.0588	0.0294	0.0000	0.0294	0.0294	0.0294	0.0294	0.0294	0.0000	0.0000	0.0294	0.0294
E1	0.0000	0.0000	0.0294	0.0294	0.0294	0.0000	0.0294	0.0588	0.0294	0.0294	0.0294	0.0000	0.0000	0.0294	0.0294
E2	0.0588	0.0294	0.0294	0.0294	0.0294	0.0294	0.0000	0.0294	0.0294	0.0294	0.0000	0.0294	0.0294	0.0000	0.0294
E3	0.0000	0.0588	0.0000	0.0294	0.0000	0.0294	0.0294	0.0294	0.0294	0.0294	0.0294	0.0294	0.0294	0.0294	0.0000

Figure 4. Normalized Direct-Influence Matrix

(3) Calculation of the Total-Influence Matrix

The total-influence matrix was derived based on the normalized direct-influence matrix.

Factor _e	A1 _e	A2 _e	A3 _e	B1 _e	B2 _e	B3 _e	C1 _e	C2 _e	C3 _e	D1 _e	D2 _e	D3 _e	E1 _e	E2 _e	E3 _e
A1 _e	0.0361 _e	0.1059 _e	0.1350 _e	0.0764 _e	0.0507 _e	0.1566 _e	0.1621 _e	0.1633 _e	0.1148 _e	0.1550 _e	0.1551 _e	0.1512 _e	0.1461 _e	0.1261 _e	0.1252 _e
A2 _e	0.0518 _e	0.0356 _e	0.0336 _e	0.0636 _e	0.0582 _e	0.0584 _e	0.0367 _e	0.0378 _e	0.0692 _e	0.0848 _e	0.1107 _e	0.1644 _e	0.1008 _e	0.1086 _e	0.1647 _e
A3 _e	0.0241 _e	0.0618 _e	0.0297 _e	0.0619 _e	0.0603 _e	0.0562 _e	0.0313 _e	0.0331 _e	0.0665 _e	0.1384 _e	0.1056 _e	0.1047 _e	0.0998 _e	0.1352 _e	0.1058 _e
B1 _e	0.0712 _e	0.1379 _e	0.1092 _e	0.0543 _e	0.0586 _e	0.1057 _e	0.1084 _e	0.1389 _e	0.1764 _e	0.2138 _e	0.2079 _e	0.1827 _e	0.1152 _e	0.1813 _e	0.1243 _e
B2 _e	0.0714 _e	0.1419 _e	0.1377 _e	0.0549 _e	0.0554 _e	0.1039 _e	0.1651 _e	0.0826 _e	0.1201 _e	0.1525 _e	0.2111 _e	0.1788 _e	0.1471 _e	0.1820 _e	0.2101 _e
B3 _e	0.0527 _e	0.0394 _e	0.0620 _e	0.0689 _e	0.0368 _e	0.0311 _e	0.0651 _e	0.0415 _e	0.0446 _e	0.1710 _e	0.1391 _e	0.1325 _e	0.1342 _e	0.1131 _e	0.1629 _e
C1 _e	0.0566 _e	0.0649 _e	0.0654 _e	0.0352 _e	0.0655 _e	0.0305 _e	0.0353 _e	0.0671 _e	0.0706 _e	0.0858 _e	0.1689 _e	0.1090 _e	0.1635 _e	0.1422 _e	0.1136 _e
C2 _e	0.0248 _e	0.0629 _e	0.0600 _e	0.0352 _e	0.0621 _e	0.0561 _e	0.0608 _e	0.0333 _e	0.0669 _e	0.1120 _e	0.1101 _e	0.1368 _e	0.1050 _e	0.1398 _e	0.1397 _e
C3 _e	0.0540 _e	0.0380 _e	0.0653 _e	0.0405 _e	0.0678 _e	0.0603 _e	0.0677 _e	0.0678 _e	0.0431 _e	0.1737 _e	0.1427 _e	0.1658 _e	0.1091 _e	0.1167 _e	0.1132 _e
D1 _e	0.0180 _e	0.0553 _e	0.0261 _e	0.0753 _e	0.0770 _e	0.0509 _e	0.0557 _e	0.0537 _e	0.0589 _e	0.0442 _e	0.0477 _e	0.0454 _e	0.0658 _e	0.0723 _e	0.0441 _e
D2 _e	0.0747 _e	0.0583 _e	0.0569 _e	0.0501 _e	0.0780 _e	0.0287 _e	0.0319 _e	0.0297 _e	0.0604 _e	0.0729 _e	0.0449 _e	0.0442 _e	0.0658 _e	0.0708 _e	0.0705 _e
D3 _e	0.0163 _e	0.0263 _e	0.0510 _e	0.0754 _e	0.0486 _e	0.0206 _e	0.0513 _e	0.0516 _e	0.0574 _e	0.0691 _e	0.0694 _e	0.0380 _e	0.0328 _e	0.0686 _e	0.0634 _e
E1 _e	0.0150 _e	0.0240 _e	0.0496 _e	0.0454 _e	0.0487 _e	0.0192 _e	0.0499 _e	0.0779 _e	0.0542 _e	0.0661 _e	0.0665 _e	0.0367 _e	0.0325 _e	0.0674 _e	0.0639 _e
E2 _e	0.0732 _e	0.0562 _e	0.0563 _e	0.0523 _e	0.0499 _e	0.0565 _e	0.0313 _e	0.0587 _e	0.0600 _e	0.0765 _e	0.0467 _e	0.0752 _e	0.0675 _e	0.0442 _e	0.0730 _e
E3 _e	0.0165 _e	0.0775 _e	0.0197 _e	0.0488 _e	0.0209 _e	0.0464 _e	0.0480 _e	0.0499 _e	0.0538 _e	0.0663 _e	0.0666 _e	0.0675 _e	0.0616 _e	0.0657 _e	0.0382 _e

Figure 5. Total-Influence Matrix

(4) Calculation of Influence Degree, Dependence Degree, Centrality, and Causality

Factor _e	Influence(D) _e	Dependence(C) _e	Centrality(M) _e	Causality(R) _e	Factor Attribute _e
A1 _e	1.8597 _e	0.6563 _e	2.5161 _e	1.2034 _e	Cause Factor _e
A2 _e	1.1789 _e	0.9859 _e	2.1649 _e	0.1930 _e	Cause Factor _e
A3 _e	1.1143 _e	0.9574 _e	2.0718 _e	0.1569 _e	Cause Factor _e
B1 _e	1.9857 _e	0.8382 _e	2.8238 _e	1.1475 _e	Cause Factor _e
B2 _e	2.0144 _e	0.8386 _e	2.8530 _e	1.1758 _e	Cause Factor _e
B3 _e	1.2948 _e	0.8810 _e	2.1758 _e	0.4138 _e	Cause Factor _e
C1 _e	1.2740 _e	1.0004 _e	2.2744 _e	0.2735 _e	Cause Factor _e
C2 _e	1.2055 _e	0.9868 _e	2.1923 _e	0.2187 _e	Cause Factor _e
C3 _e	1.3259 _e	1.1169 _e	2.4428 _e	0.2090 _e	Cause Factor _e
D1 _e	0.7904 _e	1.6819 _e	2.4723 _e	-0.8915 _e	Result Factor _e
D2 _e	0.8378 _e	1.6932 _e	2.5310 _e	-0.8554 _e	Result Factor _e
D3 _e	0.7400 _e	1.6329 _e	2.3729 _e	-0.8930 _e	Result Factor _e
E1 _e	0.7170 _e	1.4467 _e	2.1637 _e	-0.7297 _e	Result Factor _e
E2 _e	0.8775 _e	1.6340 _e	2.5115 _e	-0.7565 _e	Result Factor _e
E3 _e	0.7472 _e	1.6127 _e	2.3600 _e	-0.8655 _e	Result Factor _e

Figure 6. Summary of Influence Degree, Dependence Degree, Centrality, and Causality

Based on the total-influence matrix, the influence degree, dependence degree, centrality (M), and causality of each factor were computed.” The results are presented as follows:

(5) Calculation of the Overall Influence Matrix

Factor _v	A:1 _v	A:2 _v	A:3 _v	B:1 _v	B:2 _v	B:3 _v	C:1 _v	C:2 _v	C:3 _v	D:1 _v	D:2 _v	D:3 _v	E:1 _v	E:2 _v	E:3 _v
A1 _v	1.0361 _v	0.1059 _v	0.1350 _v	0.0764 _v	0.0507 _v	0.1566 _v	0.1621 _v	0.1633 _v	0.1148 _v	0.1550 _v	0.1551 _v	0.1512 _v	0.1461 _v	0.1261 _v	0.1252 _v
A2 _v	0.0518 _v	1.0356 _v	0.0336 _v	0.0636 _v	0.0582 _v	0.0584 _v	0.0367 _v	0.0378 _v	0.0692 _v	0.0848 _v	0.1107 _v	0.1644 _v	0.1008 _v	0.1086 _v	0.1647 _v
A3 _v	0.0241 _v	0.0618 _v	1.0297 _v	0.0619 _v	0.0603 _v	0.0562 _v	0.0313 _v	0.0331 _v	0.0665 _v	0.1384 _v	0.1056 _v	0.1047 _v	0.0998 _v	0.1352 _v	0.1058 _v
B1 _v	0.0712 _v	0.1379 _v	0.1092 _v	1.0543 _v	0.0586 _v	0.1057 _v	0.1084 _v	0.1389 _v	0.1764 _v	0.2138 _v	0.2079 _v	0.1827 _v	0.1152 _v	0.1813 _v	0.1243 _v
B2 _v	0.0714 _v	0.1419 _v	0.1377 _v	0.0549 _v	1.0554 _v	0.1039 _v	0.1651 _v	0.0826 _v	0.1201 _v	0.1525 _v	0.2111 _v	0.1788 _v	0.1471 _v	0.1820 _v	0.2101 _v
B3 _v	0.0527 _v	0.0394 _v	0.0620 _v	0.0689 _v	0.0368 _v	1.0311 _v	0.0651 _v	0.0415 _v	0.0446 _v	0.1710 _v	0.1391 _v	0.1325 _v	0.1342 _v	0.1131 _v	0.1629 _v
C1 _v	0.0566 _v	0.0649 _v	0.0654 _v	0.0352 _v	0.0655 _v	0.0305 _v	1.0353 _v	0.0671 _v	0.0706 _v	0.0858 _v	0.1689 _v	0.1090 _v	0.1635 _v	0.1422 _v	0.1136 _v
C2 _v	0.0248 _v	0.0629 _v	0.0600 _v	0.0352 _v	0.0621 _v	0.0561 _v	0.0608 _v	1.0333 _v	0.0669 _v	0.1120 _v	0.1101 _v	0.1368 _v	0.1050 _v	0.1398 _v	0.1397 _v
C3 _v	0.0540 _v	0.0380 _v	0.0653 _v	0.0405 _v	0.0678 _v	0.0603 _v	0.0677 _v	0.0678 _v	1.0431 _v	0.1737 _v	0.1427 _v	0.1658 _v	0.1091 _v	0.1167 _v	0.1132 _v
D1 _v	0.0180 _v	0.0553 _v	0.0261 _v	0.0753 _v	0.0770 _v	0.0509 _v	0.0557 _v	0.0537 _v	0.0589 _v	1.0442 _v	0.0477 _v	0.0454 _v	0.0658 _v	0.0723 _v	0.0441 _v
D2 _v	0.0747 _v	0.0583 _v	0.0569 _v	0.0501 _v	0.0780 _v	0.0287 _v	0.0319 _v	0.0297 _v	0.0604 _v	0.0729 _v	1.0449 _v	0.0442 _v	0.0658 _v	0.0708 _v	0.0705 _v
D3 _v	0.0163 _v	0.0263 _v	0.0510 _v	0.0754 _v	0.0486 _v	0.0206 _v	0.0513 _v	0.0516 _v	0.0574 _v	0.0691 _v	0.0694 _v	1.0380 _v	0.0328 _v	0.0686 _v	0.0634 _v
E1 _v	0.0150 _v	0.0240 _v	0.0496 _v	0.0454 _v	0.0487 _v	0.0192 _v	0.0499 _v	0.0779 _v	0.0542 _v	0.0661 _v	0.0665 _v	0.0367 _v	1.0325 _v	0.0674 _v	0.0639 _v
E2 _v	0.0732 _v	0.0562 _v	0.0563 _v	0.0523 _v	0.0499 _v	0.0565 _v	0.0313 _v	0.0587 _v	0.0600 _v	0.0765 _v	0.0467 _v	0.0752 _v	0.0675 _v	1.0442 _v	0.0730 _v
E3 _v	0.0165 _v	0.0775 _v	0.0197 _v	0.0488 _v	0.0209 _v	0.0464 _v	0.0480 _v	0.0499 _v	0.0538 _v	0.0663 _v	0.0666 _v	0.0675 _v	0.0616 _v	0.0657 _v	1.0382 _v

Figure 7. Overall Influence Matrix

(6) Calculation of the Reachability Matrix

According to the total influence matrix, the threshold was established at $\lambda=0.0798$ ((the mean value of the total-influence matrix) For each element of $H \geq \lambda$ was assigned a value of 1 in the adjacency matrix, and all other elements were assigned 0. The reachability matrix was then calculated accordingly.

Figure 8. Reachability Matrix

Factor _i	A1 _i	A2 _i	A3 _i	B1 _i	B2 _i	B3 _i	C1 _i	C2 _i	C3 _i	D1 _i	D2 _i	D3 _i	E1 _i	E2 _i	E3 _i
A1 _i	1 _i	1 _i	1 _i	0 _i	0 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i
A2 _i	0 _i	1 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i
A3 _i	0 _i	0 _i	1 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i
B1 _i	0 _i	1 _i	1 _i	1 _i	0 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i
B2 _i	0 _i	1 _i	1 _i	0 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i
B3 _i	0 _i	0 _i	0 _i	0 _i	0 _i	1 _i	0 _i	0 _i	0 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i
C1 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	1 _i	0 _i	0 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i
C2 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	1 _i	0 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i
C3 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i	1 _i
D1 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	1 _i	0 _i	0 _i	0 _i	0 _i	0 _i
D2 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	1 _i	0 _i	0 _i	0 _i	0 _i
D3 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	1 _i	0 _i	0 _i	0 _i
E1 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	1 _i	0 _i	0 _i
E2 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	1 _i	0 _i
E3 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	0 _i	1 _i

(7) Construction of the Centrality–Causality Quadrant Diagram

Based on the computed centrality and causality values, a centrality–causality quadrant diagram was generated to visually illustrate the relative importance and cause–effect roles of each factor.

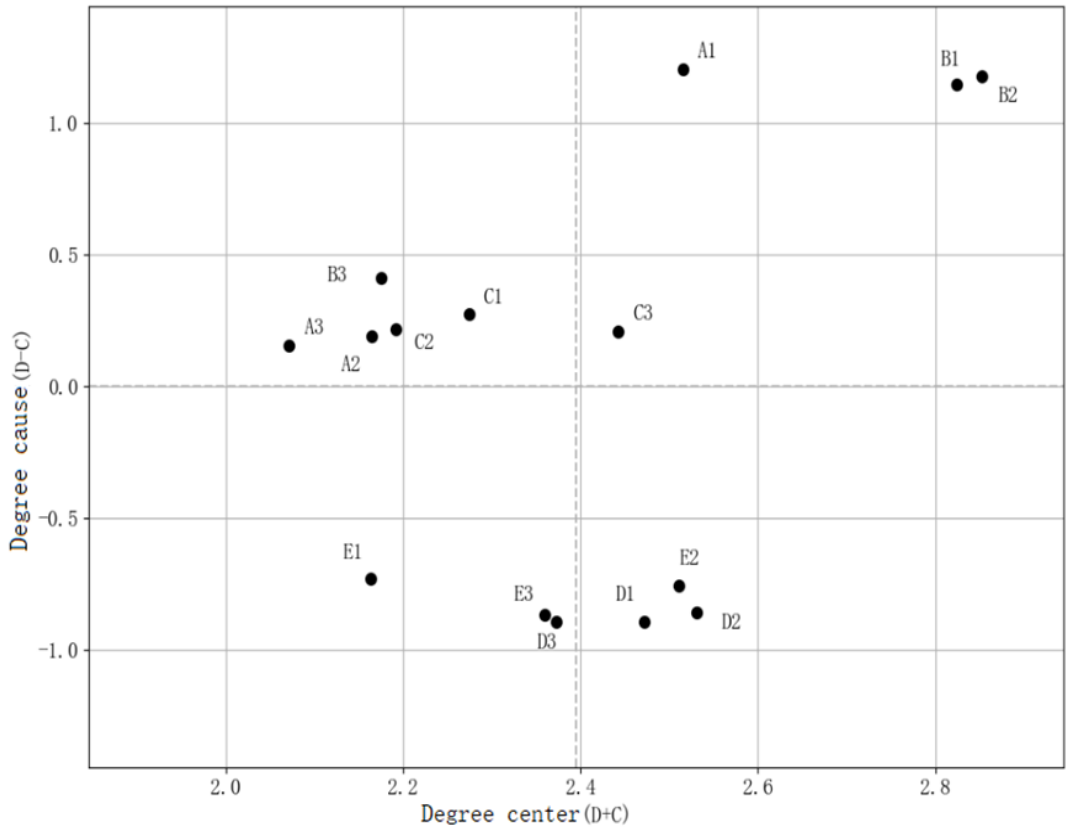


Figure 9. Centrality–Causality Quadrant Diagram
Discussion

“This paper has analyzed the determinants of the success of the urban transformation of Datong using the DEMATEL approach. The findings indicate a definite difference between causal and effect factors. All the causal factors, “A1, A2, A3, B1, B2, B3, C1, C2, and C3, are positive” causality values, which means that they drive the transformation system. Conversely, the effect factors, D1, D2, D3, E1, E2, and E3, are negative in their causality values, indicating that they are largely influenced by other factors in the system.”

B2 (industrial diversification and low-carbon upgrading) has the highest centrality (2.8530), which is why it is the most important causal factor. B1 (green investment intensity) has a high centrality value (2.8238) as well, which indicates its strong driving power. A1 (policy coherence and enforcement) is characterized by a high centrality (2.5161), and E2 (energy affordability) is also characterized by a high value (2.5115), which highlights the interdependence of the two aspects of institutional design and social welfare. B2 and B1 are also the most causal (1.1758 and 1.1475, respectively), which proves that industrial transformation and green investment are the key drivers of system-wide change. A1, which has a causality value of 1.2034, also supports its underlying role in the overall transition.

In terms of driving mechanisms, A1, B1 and B2 are evidently the dominant drivers. B2, whose degree of influence is 2.0144 and causality is 1.1758, is a decisive factor in the system and the main driver of the transformation of Datong. B1, whose degree of influence is 1.9857 and causality is 1.1475, validates the significance of sustained green investment. The main institutional factor, A1, has a degree of influence of 1.8597 and a causality of 1.2034, which highlights the significance of effective and regular policy implementation. Even though B3 (just transition financing) has a lower degree of influence (1.2948), its positive causality (0.4138) and centrality (2.1758) show that it is a supportive value in the system.

Among the effect factors, D3 (reduction in carbon and energy intensity) and D1 (air quality improvement) have the lowest causality values (-0.8930 and -0.8915), which means that they are highly dependent on upstream drivers. E3 (public participation and satisfaction) and D2 (ecological restoration and redevelopment of subsidence areas) are also highly dependent with causality values of -0.8655 and -0.8554. Although E2 (energy affordability) and E1 (employment resettlement and skill upgrading) are considered as effect factors, they indicate the limited nature of social welfare outcomes, with causality values of -0.7565 and -0.7297. The centrality values of these effect factors are also high, particularly D2 (2.5310), E2 (2.5115), and D1 (2.4723), which indicates that environmental and livelihood outcomes are important manifestations of transformation performance.

In general, B2 (industrial diversification and low-carbon upgrading) and B1 (green investment intensity) are the main factors of Datong transformation, and A1 (policy coherence and enforcement) is the necessary institutional support. These core drivers are critical to the effect factors, which means that the success of the transformation at Datong depends on the reinforcement of the synergies between B2, B1, and A1. The policymakers are advised to focus on increasing green investment, diversifying and upgrading industries faster and with low carbon, and maintaining uniformity in policy execution. At the same time, one should focus on the shifts in D1-D3 and E1 - E3, especially in the environmental quality, ecological restoration, employment transitions, and energy affordability. The systems-based approach will be essential in developing more effective and inclusive transition strategies to Datong.

3.2 ISM Model of the Success Factors in Datong's Urban Transformation

(1) Calculation of the reachability set, antecedent set, and intersection set

Based on the reachability matrix, the reachability set $R(S_i)$, antecedent set $A(S_i)$, and their intersection $R(S_i) \cap A(S_i)$ were computed for each factor.

Factor _{<i>ϕ</i>}	Reachability-Set _{<i>ϕ</i>}	Antecedent-Set _{<i>ϕ</i>}	Intersection-Set _{<i>ϕ</i>}
A1 _{<i>ϕ</i>}	A1, C1, D1, E1, A2, C2, D2, E2, A3, B3, C3, D3, E3 _{<i>ϕ</i>}	A1 _{<i>ϕ</i>}	A1 _{<i>ϕ</i>}
A2 _{<i>ϕ</i>}	D1, E1, A2, D2, E2, D3, E3 _{<i>ϕ</i>}	A1, B1, A2, B2 _{<i>ϕ</i>}	A2 _{<i>ϕ</i>}
A3 _{<i>ϕ</i>}	D1, E1, D2, E2, A3, D3, E3 _{<i>ϕ</i>}	A1, B1, B2, A3 _{<i>ϕ</i>}	A3 _{<i>ϕ</i>}
B1 _{<i>ϕ</i>}	B1, C1, D1, E1, A2, C2, D2, E2, A3, B3, C3, D3, E3 _{<i>ϕ</i>}	B1 _{<i>ϕ</i>}	B1 _{<i>ϕ</i>}
B2 _{<i>ϕ</i>}	C1, D1, E1, A2, B2, C2, D2, E2, A3, B3, C3, D3, E3 _{<i>ϕ</i>}	B2 _{<i>ϕ</i>}	B2 _{<i>ϕ</i>}
B3 _{<i>ϕ</i>}	D1, E1, D2, E2, B3, D3, E3 _{<i>ϕ</i>}	A1, B1, B2, B3 _{<i>ϕ</i>}	B3 _{<i>ϕ</i>}
C1 _{<i>ϕ</i>}	C1, D1, E1, D2, E2, D3, E3 _{<i>ϕ</i>}	A1, B1, C1, B2 _{<i>ϕ</i>}	C1 _{<i>ϕ</i>}
C2 _{<i>ϕ</i>}	D1, E1, C2, D2, E2, D3, E3 _{<i>ϕ</i>}	A1, B1, B2, C2 _{<i>ϕ</i>}	C2 _{<i>ϕ</i>}
C3 _{<i>ϕ</i>}	D1, E1, D2, E2, C3, D3, E3 _{<i>ϕ</i>}	A1, B1, B2, C3 _{<i>ϕ</i>}	C3 _{<i>ϕ</i>}
D1 _{<i>ϕ</i>}	D1 _{<i>ϕ</i>}	"A1, B1, C1, D1, A2, B2," "C2, A3, B3, C3" _{<i>ϕ</i>}	D1 _{<i>ϕ</i>}
D2 _{<i>ϕ</i>}	D2 _{<i>ϕ</i>}	"A1, B1, C1, A2, B2, C2," "D2, A3, B3, C3" _{<i>ϕ</i>}	D2 _{<i>ϕ</i>}
D3 _{<i>ϕ</i>}	D3 _{<i>ϕ</i>}	A1, B1, C1, A2, B2, C2, A3, B3, C3, D3 _{<i>ϕ</i>}	D3 _{<i>ϕ</i>}
E1 _{<i>ϕ</i>}	E1 _{<i>ϕ</i>}	"A1, B1, C1, E1, A2, B2, C2, A3, B3, C3" _{<i>ϕ</i>}	E1 _{<i>ϕ</i>}
E2 _{<i>ϕ</i>}	E2 _{<i>ϕ</i>}	"A1, B1, C1, A2, B2, C2, E2, A3, B3, C3" _{<i>ϕ</i>}	E2 _{<i>ϕ</i>}
E3 _{<i>ϕ</i>}	E3 _{<i>ϕ</i>}	"A1, B1, C1, A2, B2, C2, A3, B3, C3, E3" _{<i>ϕ</i>}	E3 _{<i>ϕ</i>}

Figure 10. Reachability Sets, Antecedent Sets, and Intersection Sets

(2) Factor Hierarchy Classification

Using the hierarchical extraction method, factors were assigned to different levels. A factor is placed in the current level when its reachability set is identical to its intersection set.

Hierarchy-Level _{<i>ϕ</i>}	Factor _{<i>ϕ</i>}
1 _{<i>ϕ</i>}	D1, D2, D3, E1, E2, E3 _{<i>ϕ</i>}
2 _{<i>ϕ</i>}	A2, A3, B3, C1, C2, C3 _{<i>ϕ</i>}
3 _{<i>ϕ</i>}	A1, B1, B2 _{<i>ϕ</i>}

Figure 11. Factor Hierarchy Classification

(3) Construction of the “Hierarchical Structural Model

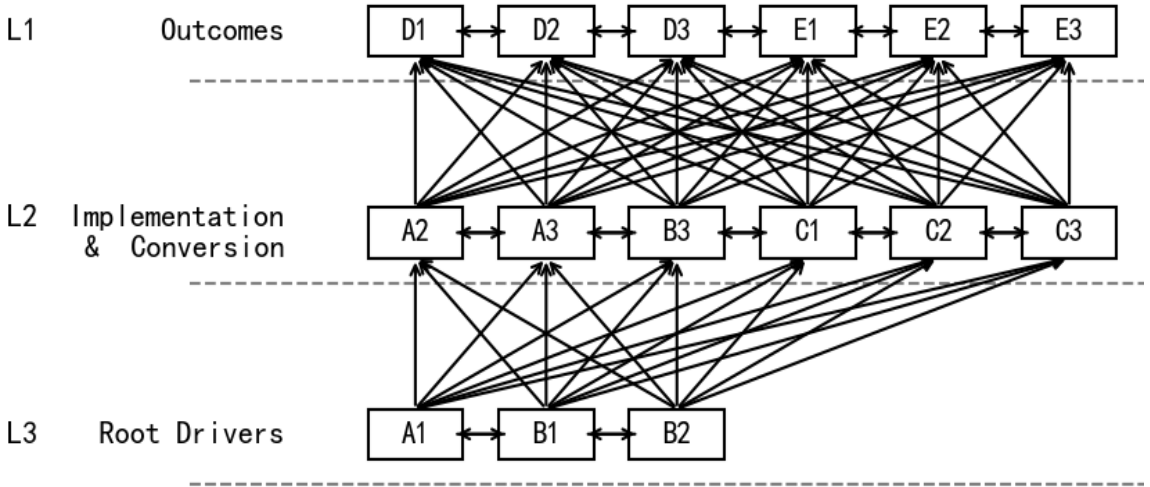


Figure 12. Hierarchical Structural Model

(4) Discussion

This paper developed an interpretive structural model among the elements that influence the success of the urban transformation of Datong and used the ISM approach to demonstrate the pathways by which various factors lead to the transition. According to the hierarchical analysis, the following conclusions can be made:

First-level (Outcome Layer) Factors: D1 air quality improvement, D2 ecological restoration and redevelopment of subsidence areas, D3 reduction in carbon and energy intensity, E1 employment resettlement and skill upgrading, E2 energy affordability, and E3 public participation and satisfaction. These aspects are the immediate consequences of the transformation of Datong. D1 represents the impact of environmental governance; D2 represents the ecological restoration potential of a resource-based city; D3 represents the progress of low-carbon transition; E1 represents the social stability of the transition; E2 represents the welfare of the residents; and E3 represents the degree of social recognition and acceptance of the change. These factors are combined to form the major indicators that can be used to measure the success of the urban transformation in Datong.

Second-level (Execution and Transition Layer) Factors: A2 cross-sector/region coordination, A3 monitoring, reporting, and verification (MRV) capacity, B3 just transition financing, C1 renewable energy penetration, C2 end-use electrification and clean heating, and C3 green mobility and charging infrastructure. These aspects are the working and transformational elements of the transition of Datong, which connects the strategic drivers to the ultimate results. A2 identifies the effectiveness of policy implementation; A3 identifies that progress is measurable, reportable, and verifiable; B3 promotes social equity in the transition; C1 optimizes the energy structure; C2 promotes clean energy consumption; and C3 supports low-carbon mobility systems. These are influenced by the underlying drivers and, consequently, have a direct impact on the outcome layer, which constitutes the key processes by which strategic objectives are converted into practical outcomes.

Third-level (Root Driver Layer) Factors: A1 policy coherence and enforcement, B1 green investment intensity, and B2 industrial diversification and low-carbon upgrading. These are the driving forces of the transformation of Datong and they are at the bottom of the hierarchy. A1 is the basic institutional situation that defines the possibility of the city to create a stable and consistent transition policy framework and guarantee successful implementation. B1 measures the intensity and magnitude of capital investment in low-carbon development, which directly affects the pace and quality of the transition. B2 offers the economic basis and growth impetus required to transform the city to lessen reliance on coal resources and seek sustainable development. These root drivers collectively constitute the transition mechanism of Datong.

In general, the results of the ISM indicate that there is a distinct hierarchical structure where the root drivers (A1, B1, B2) are the base forces, the execution layer (A2, A3, B3, C1, C2, C3) is the operational mechanism, and the outcome layer (D1-D3, E1-E3) is the transformation results. To achieve successful urban transition in Datong, it is necessary to enhance the synergy of the root drivers, provide effective execution mechanisms, and constantly monitor the results concerning the environmental quality, ecological restoration, employment, and energy affordability.

4. Policy Recommendations

The DEMATEL-ISM analysis of the urban transformation of Datong shows that a clear three-layer structure is created, comprising root drivers, execution and transition mechanisms, and outcome indicators. This model provides a systematic foundation of developing feasible policy actions. On this basis, the following recommendations are proposed to facilitate the transition of Datong to be more effective and sustainable.

(1) Strengthen the foundational drivers of transformation.

Based on the main roles of policy coherence and enforcement (A1), green investment intensity (B1), and industrial diversification and low-carbon upgrading (B2), Datong should pay attention to the alignment of long-term transition policies, the consistency of implementation mechanisms, and the growth of multi-source green financing instruments. Investing further in clean technologies, strategic emerging industries, and low-carbon infrastructure will enhance the economic and institutional foundation of transition. In particular, the industrial diversification will be integrated with the existing industrial base of Datong to create new sources of growth and reduce the risks of resource-dependence.

(2) Enhance coordination and implementation capacity.

The cross-sector coordination (A2), MRV capacity (A3), just transition financing (B3), renewable energy penetration (C1), end-use electrification and clean heating (C2), and green mobility systems (C3) implementation layer require improved institutional cooperation and governance capacity. Datong should develop one transition coordination platform that integrates the functions of government departments, energy utilities, enterprises, and financial institutions. The improvement of MRV systems will enable the evaluation of the progress of transitions in a transparent manner, and certain financial instruments, such as just transition funds, can help vulnerable groups and minimize social risks. The fast adoption of renewable energy, electrification of energy consumption, and

green transport infrastructure will contribute to the cleaner and more resilient urban energy systems.

(3) Establish comprehensive monitoring of transition outcomes.

An outcome-based continuous monitoring and feedback mechanism must be founded on outcome factors, including environmental quality, ecological restoration, carbon and energy intensity reduction, employment resettlement and skills upgrading, energy affordability, and public satisfaction. Datong should develop a holistic transition assessment system, which reports on environmental, economic, and social indicators on a periodic basis. Air quality, restoration of subsidence areas, access to clean energy, transition of the labor market, and affordability to low-income households should be given special attention. Improvement of the processes of social participation will also lead to social acceptance and adaptive policymaking.

5. Conclusion

This paper analyzes the success factors of the urban transformation of Datong by combining the DEMATEL and ISM approaches to demonstrate the causal relationships, hierarchical framework, and action channels of a complex system of transition. The findings indicate that the transition of Datong is influenced by a multilayered interaction between root drivers, execution and transition mechanisms and outcome indicators. Despite the fact that all layers participate in the overall transformation, the third-level root driver layer, which includes policy coherence and enforcement (A1), green investment intensity (B1), and industrial diversification and low-carbon upgrading (B2), is the engine of change. These factors do not only affect all the upper-layer factors, but also determine the strategic direction, institutional stability, and economic momentum that Datong needs to transform into a green and low-carbon urban system, which is not coal-dependent.

The execution and transition layer is the key interface that transforms these strategic drivers into real progress. The coordination of cross-sector (A2), MRV capacity (A3), just transition financing (B3), renewable energy penetration (C1), end-use electrification and clean heating (C2), and green mobility systems (C3) all contribute to the successful implementation of transition strategies and allow structural changes in the energy, industrial, and social systems. The outcome layer, which is reflected in the environmental quality improvement (D1), ecological restoration (D2), carbon and energy intensity reduction (D3), employment resettlement and skill enhancement (E1), energy affordability (E2), and public participation and satisfaction (E3) captures the immediate and visible outcomes of the transformation.

In general, the results indicate that the effective urban transformation of Datong is based on the core of enhancing the root drivers, which is facilitated by the effective implementation mechanisms and constant monitoring of the transition results. To guarantee long-term development, Datong should strengthen policy continuity and implementation, increase green investment, and speed up industrial diversification and low-carbon transformation. Simultaneously, the improvement of coordination, regulatory and data capacity, equitable financing of transition, and clean energy and green mobility will be necessary to transform strategic intentions into tangible successes. In addition, greater emphasis on socioeconomic justice is essential. Ensuring fair labor transitions,

protecting vulnerable worker groups, and improving the affordability of clean energy can reduce social resistance and enhance long-term resilience. These elements are critical for achieving a people-centered transformation that balances environmental ambition with citizen well-being. It is only through the combination of these factors that Datong will be able to meet several transition objectives, including environmental enhancement, ecological recovery, carbon mitigation, job security, better energy accessibility, and increased societal acceptability, which will eventually guarantee a holistic and robust change to sustainable urban development.

Future studies could extend this research in several directions. One promising area is to analyze how transition outcomes evolve under different carbon-price regimes or global energy shocks, which may alter investment incentives and the sequencing of low-carbon measures. Comparative analyses between Datong and other resource-dependent cities—both within China and internationally—would also help assess whether the hierarchical transformation model developed in this study has broader applicability. In addition, sector-specific investigations into renewable-energy manufacturing, hydrogen development, and circular-economy systems could further enrich understanding of the industrial pathways underpinning just and sustainable urban transitions.

Additional Information

The authors declare no conflict of interest.

Data availability statement

The data used in this study were collected through expert questionnaires and are not publicly available due to confidentiality considerations. However, the datasets can be obtained from the corresponding author upon reasonable request

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