Appendix I

Appendix I: Full table of the answers to the specified questions for each article

	Author(s)	SD combined with	Area of the case study	Main Characteristics that motivated combining	Most important benefits of combination	Enriched phase of SD	Theoretical consideration
1	Sanatani (1981)	Fuzzy set	The phenomena of market penetration or diffusion of new products in Segmented Populations	Fuzziness of some variables	Quantifying fuzzy concepts and parameters	Simulation phase	No mention in the article
2	Mohapatra & Sharma (1985)	Modal control theory	A company with two departments: distribution and manufacturing	No special characteristics	More rigorous method of policy design, discovering important information sources for designing realistic policies.	Simulation phase	No mention in the article
3	Coyle (1985)	Optimization	A simple model of unstable inventory dynamics	No special characteristics	Simulation via repeated optimization: for better analysis performance of SD models, it can be subjected to optimization analysis directly and immediately	Simulation phase	No mention in the article
4	Macedo (1989)	A reference model (optimization nonlinear model) and a control model (a linear quadratic: optimal control model with closed-loop solution)	Urban dynamics of POBSON model	No special characteristics	More robust policies	Simulation phase	No mention in the article

5	Dolado (1992)	Qualitative simulation	One of the most common macroeconomic models (Samuelson 1953; Dornbusch and Fisher 1984)	No special characteristics	Obtaining causal and dynamic explanations; assistance in explaining socio-economic models: helping reasoning in terms of subsystems: facilitating comprehension of models as well as forcing this reasoning to go in a different way, as with numerical simulations.	Conceptualization phase	No mention in the article
6	Seth (1994)	Fuzzy set theoretic approach	A small hypothetical company which deals in a non-durable consumer good	No special characteristics	Providing a systematic procedure for qualitative analysis of SD models, incorporating subjective beliefs and perceptions easily in an objective, scientific and rational manner using the concepts of fuzzy sets.	Simulation phase	No mention in the article
7	Van Ackere & Smith (1999)	Econometrics	Dynamics of National Health Service waiting lists	No special characteristics	More secure estimates in formulation	Simulation phase	No mention in the article
8	Gill (1996)	Social fabric matrix	Development of the Australian pollination services market	Data of social fabric matrix are based on collective wisdom and are hard such that they could be used by system dynamics models	Proposing a structured process to facilitate the active participation of system players in policy development.	SD is considered as a Dependent method	Mention
9	Schmidt & Gary (2002)	Conjoint analysis	Exploring pricing strategies for the company's existing product and analyze a variety of NPD options	This case is a kind of multi-attribute choice problems: behavioral policies of decision makers include tradeoffs among multiple attributes	Improving the formulation and validation of system dynamics models and also, its policy analysis	Simulation phase	No mention in the article
10	Powell & Coyle (2005)	Qualitative system dynamics approach as QPID (Qualitative Politicized Influence Diagrams)	A company that becomes a target for a group of activists who have threatened to adulterate its products in support of their agenda and who have, in a few cases, actually succeeded in doing so.	Involving agents and groups of agents in the system definition. A politicized system that is ubiquitous, particularly in the strategic context, and in managing them	Studying the motivations and powers of agents and thereby producing naturally an output directed at action planning at the strategic level, a complementary to numerical SD approaches, deriving components of strategic action directly from analysis.	Conceptualization phase	No mention in the article

11	Liddell & Powell (2004)	Qualitative system dynamics approach as QPID (Qualitative Politicized Influence Diagrams).	Improving patient access to general practice	It is a kind of Hybrid management problems: Access to general practice constitutes a hybrid system, having qualitative and quantitative (quantifiable) variables	Ascribing agents and actors to the connections in an influence diagram of the system, structuring thinking about the appropriate actions (aimed at these agents and actors) for managing the system behavior, deriving practical action plans for the management of challenges.	Conceptualization phase	No mention in the article
12	Schwaninger (2004)	Viable Systems Modeling (VSM)	Regional Innovation and Technology Transfer System (RITTS)	Multi-stakeholders, multi-level	Bringing the multiple actors together and help actors at different levels to achieve the requisite variety, simultaneous operation of the process at the content as well as at the context levels	Conceptualization phase	Mention
13	Rodriguez-Ulloa & Paucar-Caceres (2005)	Soft Systems Methodology	A small Peruvian company dedicated to commercialize national and imported steel products	(High) Ambiguity in the problem, conflict, multi-aspect	Introducing explicitly the observer's weltanschauung and the observer's role in SSDM studies	Conceptualization phase	Mention
14	Haslett & Sarah (2006)	Viable Systems Modeling (VSM)	Policy design in the Australian Taxation Office	Long-term capability developmental process, client involvement, emphasis on the structure and process of an organizational change, context based	Developing the formal organizational and political structures and processes necessary to support a SD intervention in a large bureaucracy, rather than modeling per se.	Conceptualization phase	No mention in the article
15	Howick et al. (2006)	Event map of scenarios	The renewable energy market in the U.K.'s electric power grid	Client center	Improving the value of the project to the client group by enabling them to visualize the links between the scenarios and the over-time dynamics that they produced, stronger analysis and a heightened degree of robustness	Conceptualization phase	No mention in the article

16	Daim et al. (2006)	**Data collection:** Patent Analysis, Bibliometrics, Analogies, Delphi **Relationship building:** Delphi,SD **Diffusion/forecasting:**SD,Scenarios, Growth curves	Forecasting technologies in fuel cell, food safety and optical storage technologies.	No historical data available, existence of several organizational factors (political, cultural and etc.), technical trend analysis alone usually cannot incorporate the organizational and political scenarios	A more complete forecasting methodology (Using SD as a platform for integrating different related methodologies)	Conceptualization and simulation phase (likely to be a pivotal method but not actually a dominant one)	No mention in the article
17	Santos et al. (2008)	Multiple-criteria decision analysis (MCDA)	Measurement and improvement of performance in radiotherapy departments	Wide range of views by multiple stakeholders	Aid of SD in exploring multiple, often conflicting, goals	Simulation phase	No mention in the article
18	Kunsch & Springael (2008)	Fuzzy techniques	Design a coherent and efficient strategic plan for a CO_2 tax scheme over a medium-term horizon, e.g. five years.	Dynamic and structural aspects of the problem, uncertainties on time-dependent key parameters or exogenous variables.	Keeping all available information, merging available data sets according to their respective credibility factors.	Simulation phase	No mention in the article
19	Adamides et.al (2009)	Soft Systems Methodology and multi-objective optimization in an action research project	Management of urban and industrial solid waste	a social issue that, beyond the purely technical, extends to both the practical (interpretivist) and emancipatory spheres of interest of the social subjects involved; multiple, subjective views; sensitivity of the public over the problem	Improving the wholeness of SD models in considering socio-economic factors	Conceptualization and simulation phases	No mention in the article
20	Duggan (2008)	A new optimization approach based on genetic algorithms	Linear supply chain network, four-agent Beer game example	Composed of A network of N agents, A set of M agent strategies, A set of agent parameters.	Allows for the varying of policy equations in order to discover the best strategies for a given problem; its scalability, in terms of the ease in adding new agents, and also how flexible it is if the modeler wishes to add new policies	Simulation phase	No mention in the article

21	Saleh et. al (2010)	Policy analysis involves three analytical components: linearization of the model, loop eigenvalue elasticity analysis (LEEA), and dynamic decomposition weights (DDW)	A simplified version of the inventory-workforce model	Dampened oscillation	policy analysis in a more structured and formal way than the exhaustive exploratory approaches; enables a much more efficient search for leverage policies, by ranking the influence of each model parameter without the need for multiple simulation experiments	Simulation phase	No mention in the article
22	Wu et.al (2010)	Agent-based modeling perspective	Technological innovation risk decision-making in an entrepreneurial team for typical enterprises	Uncertainties and conflicting information; Some relevant and conflicting objectives between upper and lower layers	New planning or decision-making ideas that improves the basic function of each agent and understanding the system from Agents' interaction, facilitates to organize the system by use of Modular Style sheets.	Conceptualization and simulation phase	No mention in the article
23	Rodríguez-Ulloa et.al (2011)	Soft Systems Methodology (SSM)	Citizen insecurity in the Province of Mendoza, Argentinia	No special characteristics	Orchestrate and implant change in social systems	Conceptualization phase	Mention
24	Hadjis (2011)	Taguchi method	Corporate planning: the market evolution module	Many ideas and relationships that are obscured in our unreliable intuition about dynamics	Identifying the probable highly uncertain and influential relationships and parameters, and testing them for sensitivity analysis early enough in an efficient and effective way.	Simulation phase	No mention in the article
25	Chen et.al (2011)	The correspondence between SD and recurrent neural network (RNN) and the genetic algorithms(GA)	Conventional world dynamics	A system of continuous flows of time-varying commodities interrelated by complex nonlinear feedback and coupling mechanisms.	Improving the system dynamics policy making in two aspects: First, it is direct; a policy maker can create an arbitrary desired reference mode directly and run the algorithm to search for the most appropriate model(s) that can fit it without heuristic objective functions or eigenvalues. Second, both the system structure and its parameter values evolve simultaneously during the search process.	Simulation phase	No mention in the article

26	Liu (2011)	Fuzzy logic	Sales and service model	Linguistic and soft variables in the model	Providing an alternative approach to incorporate linguistic variables in dynamics modeling process.	Simulation phase	No mention in the article
27	Kim & Andersen (2012)	Grounded theory	Economic system	"purposive" text data as a source of causal structures.	Using grounded theory to identify problems, key variables, and their structural relationships from purposive text data. Adding more confidence, rigor and flexibility in the modeling.	conceptualization phase	Mention
28	Liu et. Al (2012)	The coevolutionary approach	The beer distribution game (BDG): a multi-sector SD structure	Multiple independent actors who must coordinate a diverse set of decision policies, and whose decisions are intendedly rational, a kind of multi-sector models as an interconnected system of physical and information flows, where each sector is autonomous.	Offering an additional, powerful dimension to policy exploration that can be viewed as a computational extension of the ideas of partial model testing. The distinction from normal optimization methods is that, with coevolutionary optimization, individual sectors in the model can be optimized to their own fitness functions, and since a fuller range of policy responses can be investigated.	Simulation phase	No mention in the article
29	Feola et.al (2011)	Coevolutionary method (genetic algorithms (GA))	Misuse of Personal Protective Equipment that results in health risk among smallholders in Columbia	Social dynamics in the model	Exploring behavioral dynamics together with the local experts who are responsible for implementing such strategies or to provide the guidelines for it; The model was mostly used as a learning tool, which facilitated filling the gap between science and policy making	Simulation phase	No mention in the article
30	Kopainsky et.al (2012)	Conjoint analysis	Adoption of seed from improved maize varieties in Malawi	Tangible and intangible attributes besides a social dynamics factor (trust)	Allows to elicit choice preferences of stakeholders in detail and to add precision to the structure of the model	Simulation phase	No mention in the article

31	Chen et al. (2012)	Delphi method	A technology foresight case study in the Chinese information and communication technologies (ICT) industry	Mostly under the auspices of central governments, involving hundreds to thousands of experts from government, industry, academia, and research agencies in a multi-year	Identifying and evaluating key factors (variables) by nationwide experts through Delphi surveys	Conceptualization phase	No mention in the article
32	Yearworth & White (2013)	Grounded theory	Three case studies from the domains of organizational change and entrepreneurial studies	Qualitative data collection and analysis	Improving dynamic sensibility in the process of qualitative data analysis, providing a more rigorous approach to developing CLDs in the formation stage of system dynamics modeling	Conceptualization phase	Mention
33	Lee (2013)	Econometrics (applied and proven in various studies of the Bass diffusion model, discrete choice model and etc.)	The future of transportation	No special characteristics	Can have a sound theoretical background by developing the causal loop diagram which is based on the proven econometrics model	Simulation and conceptualization phases	No mention in the article
34	Kwakkel et al. (2013)	Exploratory Modeling and analysis (EMA)	Copper scarcity	Uncertainty derived from profoundly diverging views in demand side of the problem.	Extending the scenario discovery approach conceptually, technically, and practically	Simulation phase	No mention in the article
35	Kwakkel & Pruyt (2013)	Exploratory modeling and analysis (EMA)	Plausible dynamics for mineral and metal scarcity	Parametric uncertainties, orders of time delays, non-linear lookups	Help to gain insight into what kinds of surprising dynamics can occur given a variety of uncertainties and a basic understanding of the system. It is more about EMA rather than SD.	SD is considered as a dependent method	No mention in the article
36	Anderson et al. (2005)	Control theory and signal analysis techniques	A simplified but representative model of service supply chains	varying variables and information sharing	More robust policy analysis	Simulation phase	No mention in the article
37	Coyle et al. (1999)	Cognitive mapping and Mission Oriented Analysis (MOA)	Naval command and control systems effectiveness assessment	Are dependent on complex computer systems, are complex, difficult to evaluate because of the need to take into account human decision making, the need to assess potential system performance over a wide range of operational circumstances	Cognitive mapping was used to identify the processes in the system; Mission Oriented Analysis (MOA) was used to structure the inputs to the model	Conceptualization phase	No mention in the article

38	Dangerfield & Roberts (1999)	Optimization (using DYSMOD software: first optimization in SD using real world data)	The AIDS treatment-free incubation period distribution: epidemiology of AIDS	Uncertainty surrounding on the incubation period of AIDS	Improving the performance of hypothetical or generic models: genuinely useful approach to the statistical problems of estimating best fit probability distribution when the underlying data is right-censored	Simulation phase	No mention in the article
39	Evenden et al. (2006)	Geomapping and statistical analysis consisted of multivariate regression analysis, and tree-based regression analyses(CART and CHAID)	Healthcare: improving the cost-effectiveness of chlamydia screening with targeted screening strategies	It constitutes a major public Health concern, multi-disciplinary problem	Provided a unique holistic view of the problem by the contribution of the following methods: **The geomapping work**: using the software MapInfo, allowed for the spreading patterns and infection clusters to be observed. **The analysis of socio-economic indicators**: using regression models and tree-based classification trees identified high-risk groups within the population for screening intervention targeting. **The SD model**: built using the software vensim, captured the infection dynamics and cost-effectiveness of screening using strategies informed by the previous two components	Conceptualization and simulation phases	No mention in the article
40	Georgiadis & Athanasiou (2013)	Extensive numerical investigation within a simulation-based system dynamics optimization approach	Long-term capacity planning in the reverse channel of a two-product closed-loop supply chains (CLSCs) with remanufacturing activities, under a high cost setting regarding investment decisions in remanufacturing facilities.	Uncertainty in variables (actual demand, sales patterns, quality and timing of end-of-use product returns)	Providing more feasible flexible policies as improved alternatives	Simulation phase	No mention in the article

41	Homer (1999)	Stochastic job queuing model	Field service dynamics	A case in which a key table function affecting service readiness could only be properly estimated by analyzing a separate micro-level model, a model that mimics the daily queueing of service jobs and their assignment to individual field engineers.	Firm policy conclusion	Simulation phase	No mention in the article but speak greatly on the multi-methodology practice
42	Joglekar & Ford (2005)	Control theory model	Product development resource allocation	No special characteristics (the inherent closed loop flow of development work and the dynamic demand patterns of work backlogs. Projects selected are described with two important development project characteristics: complexity and concurrence).	To specify a foresighted policy, which is tested with the system dynamics model; to derive insights that are not available by either alone, but at the cost of limiting the range of applicability of the results	Simulation phase	No mention in the article
43	Olaya & Dyner (2005)	Optimization	Policy assessment in the natural gas industry	In the natural gas industry, each component has its own specific features and, when analyzed as a single whole, a synthesized modeling approach may turn appropriate; The increased number of actors and transactions, along with the deregulation of the market and the limitation of transportation capacity, generate additional uncertainty in the security of the natural gas supply.	The analysis platform handles the system complexity being modelled, improves its understanding and widens the perspectives of analysts and policy-makers.	Simulation phase	No mention in the article
44	Burcu et al. (2010)	(Monte Carlo simulations and) decision tree analysis	Wind power industry	Numerous uncertainties and high managerial flexibility	Enables handling multiple endogenous sources of uncertainty efficiently with less vulnerability to “the curse of dimensionality”; Enables a backwards induction solution approach to evaluate the project; Decision tree analysis provides an intuitive approach in modeling managerial flexibility and discrete approximations of project uncertainty	Simulation phase	No mention in the article

45	Toro & Aracil (1988)	Qualitative theory of nonlinear dynamic systems (Bifurcation Analysis: Hopf and Lotka-Volterra Types)	Ecological systems: predator-prey and the Kaibab plateau models	The cyclic behavior that can be periodic, in which case the attractor is a limit cycle; or aperiodic, resulting in a quasi-periodic orbit or a chaotic attractor	The analysis gives insight into the link between the structure of the model and its behavior modes; The interaction between mental models and all the behavior modes they can generate, emphasized by Forrester (1987), can be better understood with the help of qualitative techniques	Simulation phase	No mention in the article

Appendix II

In this table, initially, we separate main characteristics of each paper that motivated combination of SD with others from table 1 in the appendix. Then, regardless of the research problem that may have more than one specific feature, start the coding procedure. We have obtained 4 main synthesized concepts as can be seen in the table.

Appendix III: Coding procedure for finding the characteristics of the research problems

Related category	Synthesized concept	Characteristics of the problems addressed in each selected paper that motivated combination of SD with other methodologies, methods and techniques
1. Sources of Data	**a) Characteristics that are related to the involved agents and their divergent views**	• Multiple stakeholders • Involving agents and groups of agents in the system definition. • Client involvement, Client center • Involving hundreds to thousands of experts from government, industry, academia, and research agencies • Multiple independent actors who must coordinate a diverse set of decision policies, and whose decisions are intendedly rational, a kind of multi-sector models as an interconnected system of physical and information flows, where each sector is autonomous • Uncertainty derived from profoundly diverging views • Wide range of views • The problem is a social issue that, beyond the purely technical, extends to both the practical (interpretivist) and emancipatory spheres of interest of the social subjects involved.

		• It involves a kind of social dynamics • Composed of A network of N agents, A set of M agent strategies, A set of agent parameters (structure of the problem) • Multiple, subjective views • Relevant and conflicting objectives between upper and lower layers
2. Content of data	**b) Characteristics that are related to the variables and formulations of causal relations**	• Fuzziness of some variables • Quantitative and qualitative data • Linguistic and soft variables in the model • Uncertainty in variables. • varying variables and information sharing • Uncertainties and conflicting information • Uncertainties on time-dependent key parameters or exogenous variables • Tangible and intangible attributes besides social dynamics factor(trust) • Behavioral policies of decision makers include tradeoffs among multiple attributes • Parametric uncertainties, orders of time delays, non-linear lookups • Human decision making • Dampened oscillation behavior • Existence of data from Social Fabric Matrix (that are based on collective wisdom and are hard such that they could be used by system dynamics models.) • No historical data available • “Purposive” text data as a source of causal structures
	c) Characteristics that are related to the nature of the problems	• Multi-level, multi-aspect • Multi-disciplinary; several organization factors—political, cultural, etc. • Complexity • Dynamic and structural aspects of the problem • (High) Ambiguity in the problem • Queueing nature of problem • Many ideas and relationships that are obscured in our unreliable intuition about dynamics • A system of continuous flows of time-varying commodities interrelated by complex nonlinear feedback and coupling mechanisms • Qualitative data collection and analysis • Each component has its own specific features and, when analyzed as a single whole, a synthesized modeling approach may turn appropriate • Dependent on complex computer systems • Cyclic behavior that can be periodic

		• Long-term capability developmental process • Wide range of operational circumstances • Emphasis on the structure and process of an organizational change • The relevance of human decision making
3. Context of data	**d) Characteristics that are related to the contexts of the problematic situation**	• A politicized system (that is ubiquitous, particularly in the strategic context, and in managing them it is necessary to take the political aspects of power into account at an early stage in the analysis). • Mostly under the auspices of central governments • High managerial flexibility • Sensitivity of the public over the problem • A major public Health concern

Appendix IV

In this table, initially, we separate benefits of each combination for SD from table 1 in the appendix. Then, start the coding procedure. We have obtained 4 main synthesized concepts as can be seen in the following table.

Appendix III: Coding procedure for finding the benefits of combination for SD modeling

Synthesized concept: Improved capabilities of system dynamics modeling as a result of combination	**Benefits of methods in each selected paper for system dynamics modeling**
1. Improved capabilities in obtaining and quantifying non-objective information	• Incorporating subjective beliefs and perceptions • Quantifying fuzzy concepts and parameters • Keeping all available information, and merging available data sets according to their respective credibility factors. • More holistic way in considering socio-economic factors • Identifying and evaluating key factors (variables) by nationwide experts through Delphi surveys. • Providing an alternative approach to incorporate linguistic variables in dynamics modeling process. • Identify problems, key variables, and their structural relationships from purposive text data.
2. Added confidence, rigor, precision and flexibility in the components of SD modelling	• Adding more confidence, rigor and flexibility in the modeling • Better analysis performance of system dynamics • Systematic procedure for qualitative analysis • Secure estimate

	• Improving the formulation and validation of system dynamics models and also, its policy analysis • Identifying the processes in the system (using Cognitive mapping) • Improving dynamic sensibility in the process of qualitative data analysis, providing a more rigorous approach to develop CLDs in the formation stage of system dynamics modelling • Sound theoretical background by developing the causal loop diagram which is based on the proven economic model. • Improve of its understanding and widening the perspectives of analysts and policy-makers. • Identifying the probable highly uncertain and influential relationships and parameters, and testing them for sensitivity analysis early enough in an efficient and effective way. • Improving the performance of hypothetical or generic models: genuinely useful approach to the statistical problems of estimating best fit probability distribution when the underlying data is right-censored • Enables handling multiple endogenous sources of uncertainty efficiently with less vulnerability to "the curse of dimensionality".
3. Added rigorous and robust policy exploration, design and analysis	• More robust policies • More rigorous method of policy design, • Useful insights into possible future scenarios • Designing realistic policies. • Visualize the links between the scenarios and the over-time dynamics that they produced, stronger analysis and a heightened degree of robustness (could be more) • A more complete forecasting methodology, using SD as a platform for integrating different related methodologies. • Allows for the varying of policy equations in order to discover the best strategies for a given problem, its scalability, in terms of the ease in adding new agents, and also how flexible it is if the modeler wishes to add new policies. • Perform the model's policy analysis in a more structured and formal way than the exhaustive exploratory approaches. This method enables a much more efficient search for leverage policies, by ranking the influence of each model parameter without the need for multiple simulation experiments. • Firm policy conclusion • More robust policy analysis • Improving the system dynamics policy making in two aspects: First, it is direct; a policy maker can create an arbitrary desired reference mode directly and run the algorithm to search for the most appropriate model(s) that can fit it without heuristic objective functions or eigenvalues. Second, both the system structure and its

	parameter values evolve simultaneously during the search process. • Providing more feasible flexible policies as improved alternatives • Extending the scenario discovery approach conceptually, technically, and practically. • To specify a foresighted policy, which is tested with the system dynamics model to derive insights that are not available by either alone, but at the cost of limiting the range of applicability of the results • Offering an additional, powerful dimension to policy exploration that can be viewed as a computational extension of the ideas of partial model testing. The distinction from normal optimization methods is that, with coevolutionary optimization, individual sectors in the model can be optimized to their own fitness functions, and since a fuller range of policy responses can be investigated. • Decision tree analysis provides an intuitive approach in modeling managerial flexibility and discrete approximations of project uncertainty. • Can explore the search space in order to discover the best combination of parameters and equation-based strategies for a given system dynamics problem.
4. Consideration of agents and their influencing attributes and views in SD modelling	• Ascribing agents and actors to the connections in an influence diagram of the system • Bringing the multiple actors together and help actors at different levels to achieve the requisite variety • Active participation of system players in policy development. • Introducing explicitly the observer's weltanschauung and the observer's role in SSD studies; • Studying the motivations and powers of agents • New planning or decision-making ideas that improves the basic function of each Agent and understanding the system from Agents' interaction, facilitates to organize the system by use of Modular Style sheets. • Exploring behavioral dynamics together with the local experts who are responsible for implementing such strategies or to provide the guidelines for it. The model was mostly used as a learning tool, which facilitated filling the gap between science and policy making. • Allows to elicit choice preferences of stakeholders in detail and to add precision to the structure of the model.
5. Developing structures and processes for support of SD intervention and implementation	• Developing the formal organizational and political structures and processes necessary to support a system dynamics (SD) intervention in a large bureaucracy, rather than modelling per se. • Simultaneous operation of the process at the content as well as at the context levels. • Orchestrate and implant change in social systems, based on a multi-methodological and multi-paradigmatic approach