KEDGE BUSINESS SCHOOL
ILS2016
Information Systems Logistics and Supply Chain
6th International Conference
université de BORDEAUX

# Synchromodal Transport: Pre-requisites, Activities and Effects

P.M. Singh, M.J van Sinderen and R.J Wieringa

Services, Cyber Security and Safety.
University of Twente, Enschede, The Netherlands
*{p.m.singh, m.j.vansinderen, r.j.wieringa}@utwente.nl*

**Abstract.** Synchromodal Transport is one of the most innovative concepts in logistics. But, there is considerable ambiguity in existing literature over a common reference point for SmT. In this paper we consolidate existing research domain of SmT, by proposing a common reference point for pre-requisites, activities and effects of SmT. Our research will benefit future researchers and logistic companies willing to move towards Synchromodal Transport.

**Keywords.** Synchromodal, logistics, transport, multimodal, sustainable, intermodal, co-modal.

## 1. Introduction

Logistics research has gradually seen an accumulation of different terms to describe the current and future (desired) transport scenarios [1]. These terms are *multimodal (MM), intermodal (IM), co-modal (CM)* and *synchromodal transport (SmT)*. The underlying concepts of these terms are summarized in [1],[2],[9] and [11]. Yet, as discussed in [1],[2] and [9], all these terms have considerable overlapping features leading to confusion. In this paper our focus is on SmT because, although, SmT is instrumental for attaining the EU goal of sustainable logistics [17], yet there is an absence of a common understanding over SmT and on activities to be performed in SmT [4].

*Synchromodal transport* (SmT) is one of the most innovative concepts in logistics. After the term was first used in 2011 [3], researchers have been quick to recognize its applicability and usefulness and thus it has gained ample interest [1],[8]. But, in the absence of a common definition, different authors have attributed different features to it, which has led to an overloading of the term, SmT [4]. Although, there surely are features of SmT on which the authors agree, but a clear foundation and a common reference point is missing. This is not ideal for future research on the topic. Our goal, in this paper is to propose a common foundation for future research over SmT. We do this by a systematic literature review.

A common issue which exists in SmT research currently, is the prevalence of different terms used to refer to identical concepts. E.g., demand consolidation is referred as *bundling*

in [14] as *consolidation of load* in [10] and as aggregation of demand in [9]. The main contribution of our paper, is a collection and categorization of all such terms from the literature, to provide a better and consistent understanding of SmT. Furthermore, our research would be instrumental for logistic companies in achieving the benefits of SmT.

## 2. Background

In this section we discuss some important publications over SmT. In [2] five different definitions of SmT from various sources are mentioned. A detailed study of key enablers for SmT based on 11 research publications is presented in [14]. A similar study on enablers and barrier for SmT is done in [12]. These enablers are then divided into 4 categories, Transactional, Governmental, Institutional and Cultural. A framework for SmT having 5 components is discussed in [15]. These components are, Infrastructure, Shipper, Control and Co-operation, Dynamics and Network & Organization. Due to space constraints these components are not discussed further. In [5] a comprehensive list of EU (and Dutch) funded projects related to SmT is given. The findings and implementation of these projects (e.g. [13]) will have a big impact on future research over of SmT. Wilhelmsson et al. in [16] carried out a detailed literature research on logistic publications dealing with optimal integration of different modes of transport. They concluded that despite continued push for sustainable logistics by EU, *"transport patterns have not changed much"* [16].

A comprehensive literature research which incorporates different viewpoints over SmT domain is missing. This lack of research coupled with the need for an unambiguous definition, forces researchers to come up with their own definition while describing SmT in their publications. Via a systematic literature review, we included the main results and viewpoints from key researches in SmT domain, including most of those mentioned above.

## 3. Research Methodology

To achieve our research goal we did a systematic literature review (SLR) based on guidelines given in [19]. In this section we elaborate the methodology for our SLR. First, we formulated research questions and chose the search terms. Then, we selected 10 databases (i.e. Google Scholar, IEEE Xplore, JSTOR, Springer Link, Web Of Science, Emerald Insight, Science Direct, Scopus, EBSCO-Elite and DBLP) to search relevant papers. Based on the search results from these databases we formulated our inclusion and exclusion criteria. The review process was conducted by the authors working as a team.

**Research questions.** Our research questions are as follows;
R.Q 1. What are the characteristics of SmT?
R.Q 2. Which research institutes are most active in this field?

R.Q 3. What is the publication trend over SmT in recent years?

RQ 1 is for the collecting definitions, terms and key viewpoints from all researches in SmT domain. We formulated two additional research questions (RQ 2 and RQ 3) to evaluate the proliferation of the term SmT and its research progress over the years.

**Search strategy.** At the start of the search process, our search string was *Synchromodal** but it resulted in false positives, e.g. papers over synchromodal learning environments and optics. We then refined it as: *Synchromodal* AND (transport* OR logistic*)*. Additional constraint was language (i.e. English). Some online databases had restrictions on the coverage of the search i.e., full text, abstract or/and title. In each of the databases we did the most elaborate search possible. We got a total of 137 results. To retrieve relevant papers from these results, 3 rounds of selection criteria were applied.

Round 1 – Inclusion. In first round, the inclusion criteria were (a) paper is about logistics, and (b) paper is published in a peer reviewed publication.
(b) was more relevant for Google Scholar. In other online databases the search results were by default from peer reviewed sources. In this round 87 papers were included.

Round 2 – Exclusion. If there did not exist an ample evidence to clarify what the author(s) means by SmT, then the paper was excluded. This is done, to remove those papers where the term is mentioned without any explanation. The list of excluded paper was then reviewed by another researcher and any disagreements were solved by a meeting. After this round, 31 papers were excluded, leaving a list of 56 papers.

Round 3 – Exclusion. We excluded duplicate papers, which left us with 30 papers.

## 4. Results

In the final list of the candidate papers, only few papers discussed SmT in detail. Therefore, we divided the papers based on their relevance, where relevance measures level of *detail,* in which SmT is discussed. Papers, whose main topic is SmT are of high relevance and were classified as *Primary*. In *Secondary* papers SmT is not the main topic of the paper but the concept is sufficiently discussed. In *tertiary* papers, SmT was discussed but only briefly, and thus they have the lowest relevance. Such a classification is prone to bias, so each of the authors made a list of the papers based of the above classification, independently, and then the lists were compared and combined to obtain, a final list. Any disagreements were solved in a meeting. See Appendix A for the above classification of the papers.

In each of the 30 papers we searched for the definitions, features and properties of SmT. We found a total of 55 terms (words and phrases) used to describe SmT, which were then classified by each of the authors separately. They divided the terms into 8, 6 and 6 different categories. These categories though not identical had considerable overlapping between them. Consensus was reached in a meeting among the authors and a new and simple categorization of terms was made. All the 55 terms were now divided into just three

categories, *Pre-requisites, Activities* and *Effects.* Such a classification better suited our research objectives. See Appendix B.

### 4.1 Research Question 1

Different researchers have used different terms to refer to the same underlying concept, e.g. *bundling, aggregation of demands, consolidation of load and synchronization of demand* all refer to the same concept. Moreover, we found that while describing SmT, researchers rarely discussed the pre-requisites or effects of SmT. Therefore for a new reader, reading about SmT gives a lot of disorganized information.


**Fig. 1**: Relationships

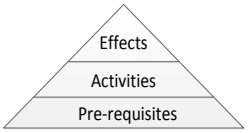


**Fig. 2**: Hierachy

**Pre-requites.** Successful implementation of SmT requires certain pre-requisites to be met. Key pre-requisites (or enablers) for SmT include co-operation between stakeholders, IT support and an advanced physical infrastructure [6], [14]. Additionally, logistic companies have to identify which routes and corridors are best suited for SmT logistics owing to large traffic volumes or frequency of disruptions [7]. Of the 69 terms found from literature, 17 were classified as referring to the pre-requisites of SmT. Further, these 17 terms were divided into three broad categories, as follows:

*Policies.* Better policies are required at two levels, government level (i.e. infrastructure development, tax incentives for sustainable logistics) and at company level (mutual trust development, co-operation instead of competition [14]).

*Infrastructure.* Appropriate infrastructure is critical for SmT logistics. It concerns development of hubs, inland waterways, improvement at key hubs, connections with smart cities [8].

*Technology.* IT coordination is a critical pre-requisite for SmT, for enabling information sharing, track and trace and access to real time information. Out of the 11 sources consulted in [14], 7 considered Information/Data/ICT/ITS as a key enabler for SmT. Companies frequently have constraints over data sharing, privacy and ownership of data. Policies should be made to overcome these constraints to allow seamless data sharing.

**Activities**. Once the required pre-requisites are met, a logistics company can move towards SmT activities, wherein, it should perform some new processes like real time modal shift and some existing processes differently like better planning, better allocation of orders and disruption handling [10]. 18 terms found from literature were classified as referring to the activities of SmT, further divided into 4 categories i.e. *Smart Planning, Disruption Handling, Dynamic switching and Demand Aggregation*.

**Effects.** The positive effects of SmT are the reason for the interest it has received among researchers and practitioners. It is an important contributor to EU goal of *sustainable mobility*. SmT has benefits for environment (reduction in $CO_2$ emissions and reduced pressure on roads), for logistics companies (cost reduction) and the entire supply chain (flexible, integrated) [17]. 20 terms were classified as referring to the effects of SmT and were further divided into 4 categories, *Environmental, Better resource utilization, Cost Reduction, Supply chain improvements.* See Appendix B.

As an example of possible usage of the categorization above, consider Fig. 3. To achieve Better Resource Utilization (an effect), a logistic company must perform Demand Aggregation and Smart Planning (activities). This can only be achieved when there are advanced IS to use and analyze contextual information in real time like demand, delays, disruptions etc. [10]. These in turn require better policies, contracts and service level agreements with clients and partners. Thereby, making Policy making and Technological support as pre-requisites. Similar relationships would exist between other elements also. Fig.3 is meant to be just an example. These relationships will help logistic companies to achieve benefits of SmT. Thus, SmT is a layered concept as shown in Fig. 2.

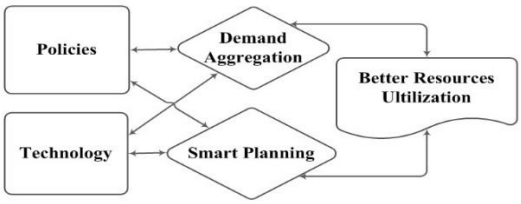


**Fig. 3**: Causality

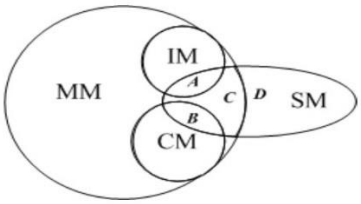


**Fig. 4**: Relationship with IM, CM and MM

MM (multimodal), IM (intermodal), CM (co-modal) and SmT are overlapping concepts since they represent a continuous maturity model for logistics. In [2] the relationship between these concepts is brought out clearly. We further improve the conceptualization of the relationships among them in Figure 4. Fragment A represents IM transport, which also involves SmT activities, like dynamic switching and real time disruption handling. B represents SmT where 2 transport modes are used simultaneously (thus co-modal also). E.g. use of both barge and truck based on demand aggregation. Fragment C consist of SmT where the loading unit is opened (thus not intermodal) and D, consists of SmT which involves 2 identical modes of transport (e.g. dynamic switching between trucks loads)

### 4.2 Research Question 2

We tabulated author affiliations of all papers, to investigate current and upcoming institutes conducting research in SmT domain. Such a table also allowed us to evaluate proliferation of the term SmT outside NL, keeping in mind that it is relatively a new concept. The most important conclusions were. Firstly, most of the research over SmT, **is still** concentrated in

NL. TUDelft has the most publications i.e. 6 (1 primary, 3 secondary, 2 tertiary), followed by Erasmus University, Rotterdam and TNO (NL) i.e. 4 each (1 primary, 1 secondary and 2 tertiary, also for each). Secondly, there is considerable collaborations between universities working on SmT. But, Dutch universities are not collaborating among themselves. Thirdly, SmT is discussed in detail in primary papers from Poland and Austria and in secondary papers from Germany, Denmark and UK. Thus, our research has reinforced the belief that awareness and research over SmT is growing within Europe.

### 4.3 Research Question 3

Of the 30 papers used for this literature review, 16 were journal papers and 14 were conference papers. We divided the sources of the papers into 4 classes, namely, (a) Transport or Logistics (e.g. Journal of Shipping and Transport, European Transport Law, etc.), (b) Information Systems (e.g. IFIP IWEI, Networking Sensing and Control, etc.), (c) IS for Logistics and Transport (e.g. Computational Logistics, Information Systems Logistics and Supply Chain, etc.), (d) Others (e.g. Chain and Network Science, Electronic Government Research, etc.). 15 papers were from Transport or Logistics publications, 3

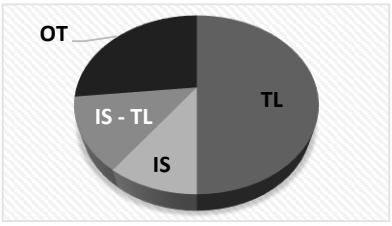


**Fig. 5**: Publication Sources

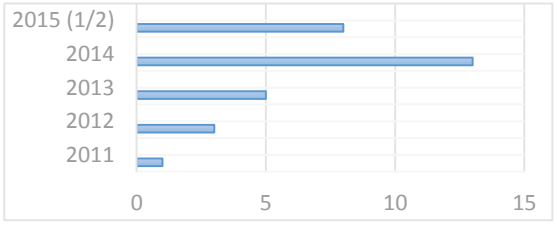


**Fig. 6**: Publications vs Years

were from Information Systems publications, while 4 were from IS for Transport and Logistics publications. 8 of the papers were did not belong to any of the above categories (Fig. 5). Such a classification showed us the prominent research communities involved in SmT research. Additionally, as can be seen from Fig. 6, there has been a slow but consistent increase in research publications discussing SmT. For 2015, publications till the first half of 2015 are counted.

## 5. Discussion and future work.

In this section we further discuss some key results from our research. In round 1 of our selection criteria (Sec. 3), we included only peers reviewed papers. MSc. thesis, online publications and project reports were excluded. Nevertheless, they contain important developments and results related to SmT. Study of these sources are for future research.

The validation of the pre-requisites, activities and effects must be done with representatives of logistics companies. Do the effects of SmT mentioned in literature align with those which the companies seek? Are some benefits of SmT more lucrative/important than others? These are some important questions which still need to be answered. We plan to conduct interviews with companies to answer these. One important question which has not be addressed, is, about the short (and long)-term demerits of SmT, if any. If they exist, they could be a reason for companies being resistant towards SmT. Furthermore, none of the papers, we studied, have discussed the relationships among SmT, Intelligent Transport Systems (ITS) and Smart Logistics (SL) [8]. These terms could be used by authors unaware of SmT for specifying logistic activities similar to SmT activities. We are of the view that concepts, learnings and results from ITS and SL, should be used in SmT research and implementation to avoid duplicity of research. We are hopeful that future researchers will address this open issue.

Advanced IS is a pre-requisite for SmT [6],[8],[10], essential for data exchange, smart planning and co-ordination between different logistic partners. In our research, we found that most researchers are aware of the IS challenges of SmT, but only 7 out of 30 papers mentioning SmT were published in sources over IS (or IS for logistics). Although, there is ample research over ICT support for logistics [1], in general, it is important for the SmT research progress that it receives more attention from the IS community. Results from previous implementations of ICT support for advanced logistics (e.g. [18]) must be studied and used for SmT. Although the word SmT has not been used but the result of such researches have to be applied to SmT to avoid duplicity of research. Some examples of EU projects are, DiSCwise, Euridice, e-Freight, ALICE and Smart-CM [18]. A review of EU projects in ICT developments for multimodal transport is given in [11].

We started our paper, by mentioning that numerous overlapping definitions for SmT exist. This is the precise reason, why we *don't* give a new definition in this paper. But, none of the existing definitions found in the papers were complete. We propose that future researcher build upon and add new elements to the list of pre-requisites, activities and effects of SmT proposed by us. Causal relationships between elements (as in Fig. 3) have to be investigated and verified.

## 5. Conclusion

SmT is the future of transport, having benefits for logistic companies, consumers and environment. Therefore, an unambiguous and consistent terminology of SmT, is required. We clarified the concept of SmT and made an exhaustive list of pre-requisites, activities and effects of SmT. This would make the road towards SmT easier for logistic companies. We have contributed towards a theoretical foundation for future research over SmT. An overview of publication trends for SmT was also discussed. Our research can be a common reference point for future studies.

## References

1. SteadieSeifi, M., Dellaert, N.P., Nuijten, W., van Woensel, T., Raoufi, R.: Multimodal Freight transport planning: A literature review. European J. of Operational Research. 233, 1-15 (2014)
2. Reis, V.: Should we keep on remaining a +35 year old baby? Jou. of Transport Geography. 46. Pp. 173-179 (2015)
3. Verwij, C. A., Synchromodal Transport: Efficient en duurzaam transport via netwerkregie, http://bit.ly/1TeFJ3x
4. van Riessen, B., Negenborn, R.R., Dekker, R.: Synchromodal Container Transportation: An overview of current topics and research opportunities. In: Corman, F., et al. (eds.) ICCL 2015, LNCS 9335, pp. 386-397. Springer International Publishing Switzerland (2015)
5. Meng. Lu.:Synchromodality for enabling smart transport hubs. In: Proceedings of Int. Conf. on Traffic and Transport Engineering. pp. 875-881. Belgrade. (2015)
6. Panagakos, G.P., Psaraftis, H.N. How green are the TEN-T core network corridors? In: Proceedings Transport Research Arena (2014)
7. Meng, Lu., Galvez-Borbon, Y.: Advanced Logistic and supply chain managements for intelligent and sustainable transport. In: Proceedings 19th World Congress on ITS, Vienna. (2012)
8. Oonk, M.E. Smart logistics corridors and the benefit of Intelligent Transport Systems. In: Proceedings Transport Research Arena (2014)
9. Pleszko, J.: Multi Variant Configurations of Supply Chains in the Context of Synchromodal Transport. LogForum 8.4 pp. 287-295 (2012)
10. Singh, P.M., van Sinderen, M.J.: Interoperability challenges for context aware logistics services – The case of Synchromodal Logistics. In: Zelm, M., (eds.) IWEI-WS. CEUR Vol. 1414 (2015).
11. Harris, I., Wang, Y., Wang, H.: ICT in multimodal transport and technological trends: Unleashing potential for the future. Int. J. Production Economics. 159, 88-103 (2015)
12. Tavasszy, L. A., Behdani, B, Konings, R.: Intermodality and Synchromodality, http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2592888
13. Corridors, Hubs and Synchromodality. Research and innovative Roadmap, http://www.etp-logistics.eu/wp-content/uploads/2015/08/W26mayo-kopie.pdf
14. Putz, L., Haider, C., Haller, A., Schauer, O.: Identifying Key Enablers for Synchromodal Transport Chains in Central Europe. In: Proceedings WCTRS SIGA2 2015 Conference (2015)
15. Lucassen, I.M.P., Dogger, T.: Synchromodality pilot study: Identification of bottlenecks and possibilities for a network between Rotterdam, Moerdijk and Tilburg. TNO 2012 P10128 (ver. 1.0), Delft.
16. Eftestol-Wilhelmsson, E., Bask, A., Rajahonka, M.: Intermodal Transport Research- a law and logistics literature review with EU focus. European Transport Law. Vol. 49. No. 6, 609-674 (2014).
17. Singh, P.M.: Developing a service oriented IT platform for synchromodal transportation. In: Meersman, R., et al. (eds.) OTMA Workshops 2014. LNCS, vol. 8842, pp 30-36. Springer Berlin Heidelberg. (2014)
18. Pedersen, J. T.: One common framework for information and communication systems in transport and logistics: Facilitating Interoperability. In: Golinska, P., Hajdul, M. (eds.) Sustainable Transport, EcoProduction. Environmental Issues in Logistics and Manufacturing, pp. 165-196. Springer-Verlag Berling, Heidelberg (2012)
19. Kitchenham B (2007) Guidelines for performing Systematic Literature Reviews in Software Engineering, Version 2.3, EBSE Technical Report EBSE-2007-01, Keele University and University of Durham

## Appendix A: List of candidate papers.

**Primary**
P1. Synchromodal Container Transportation: An Overview of Current Topics and Research Opportunities (2015)
P2. Interoperability challenges for context-aware logistic services-The case of synchromodal logistics (2015)
P3. Identifying Key Enablers for Synchromodal Transport Chains in Central Europe (2015)
P4. Developing a service oriented IT platform for Synchromodal Transportation (2014)
P5. Control Tower Architecture for Multi–and Synchromodal Logistics with Real Time Data (2015)
P6. Multi−Variant Configurations of Supply Chains in the Context of Synchromodal Transport (2012)
P7. Synchromodality for enabling smart transport hubs (2014)

**Secondary**
S8. Multimodal freight transportation planning: A literature review (2013)
S9. Service network design for an intermodal container network with flexible transit times and the possibility of using subcontracted transport (2015)
S10. Smart logistics corridors and the benefits of Intelligent Transport Systems (2014)
S11. Future Logistics - Challenges, Requirements and Solutions for Logistics Networks (2013)
S12. Enhancing visibility in international supply chains: The data pipeline concept (2012)
S13. A Web-Based Data Pipeline for Compliance in International trade (2011)
S14. Advanced logistics and supply chain management for intelligent and sustainable transport (2012)
S15. Should we keep on renaming a+ 35-year-old baby (2015)
S16. How green are the TEN-T core network corridors? (2014)

**Tertiary**
T17. Intermodal Transport Research: A Law and Logistics Literature Review with EU Focus (2014)
T18. ICT in multimodal transport and technological trends: Unleashing potential for the future (2014)
T19. Impact and relevance of transit disturbances on planning in intermodal container networks using disturbance cost analysis (2014)
T20. An efficient genetic algorithm to solve the intermodal terminal location problem (2014)
T21. Driving forces and challenges for the Flemish-Dutch Delta for 2040: a multi-actor analysis (2012)
T22. Floricultural supply chain network design and control: industry needs and modelling challenges (2015)
T23. An exploratory analysis of the effects of modal split obligations in terminal concession contracts (2014)
T24. Maritime policy in the North Sea region: Application of the cluster approach (2014)
T25. Roadmap towards a smart logistics ecosystem (2014)
T26. The Railway System Transformation – Implementation Of The Interoperability Requirements On The Rail Network (2014)
T27. Towards a vision of goods transport in 2040: Dealing with volatility (2013)
T28. Cooperation between Waterways and Railways, an Unnatural Alliance Rail Strategic Development of River Ports in the Greater Paris Region (2014)

T29. Hybrid control of supply chains: a structured exploration from a systems perspective (2013)
T30. Challenges of the New Urban World (2015)

## Appendix B: Categorization of terms.

| Pre-requisites |
|---|
| **Policies** |
| Integrating policies [P3, S16, P7] |
| Integrating governance [P7] |
| Decision Making [P1, S11, T25] |
| Legal [P3,S16] |
| Central Network Orchestrator [P1] |
| Co-operation [P3] |
| **Infrastructure** |
| Integrated transport systems [P1, S11, P3, T30] |
| Integrating infrastructure [S16, P7] |
| Coordination of logistics chains [S15, P5, T25] |
| Integrating services [P7] |
| Holistic view of transport network [P7] |
| Aggregation of different modes into a coherent service [S15, T28] |
| **Technology** |
| Integrating technology [S11, P7] |
| Advanced IS [P3,S16] |
| Real time information [T27, S13, P7] |
| Data [P9, P1, P7] |
| Sharing real time information [T21] |

| Activities |
|---|
| **Disruption Handling** |
| Coping with disruption [P1, P2, P3, P4, T19] |
| Handling uncertain circumstances [S15, P3] |
| Coping with delays [P1, P2, P3, P4, T19] |
| **Dynamic Switching** |
| Dynamic switching [S8, S11, T22] |
| Real time switching [S8, S9, P1, P2, S11, P3, S15, S16, T18, T19, P6, T21, T22, T26, S12, T27, S13, T29] |
| Intermediate transfers [S9, T19] |
| Switching between modes [S8, S11] |
| **Demand Aggregation** |
| Bundling [S8, S11, P3, P6, P7] |
| Aggregate demands [P2, S15, P6] |
| Consolidation of load [P2] |
| Synchronization of demand [S15] |
| **Smart Planning** |
| Dynamic Planning [S11] |
| Better Planning [S10, P1, P7] |
| Real time decision making [S8, P3, T29] |
| Choice based on current circumstances [T17, S8] |
| Best mode selection of all time [S8, S10, P1, S15, P6, T20] |
| Real time adaption [S15, P5, T18, T24, T29] |
| Ability to decide at real time [P1] |

| Effects |
|---|
| **Supply chain improvements** |
| Structured combination [S8, T20] |
| Supply chain visibility [S13] |
| Synchronized combination [S8, T20] |
| Efficient [S8, P1, S11, P3, S15, T20, S14] |
| Optimal alignment [P1, P3, P6, T23] |
| Reliable [S8, S15, P6, T28] |
| Integrated [S11, S15] |
| Traceability [S9, P4] |
| Flexible [S8, P1, S11, P3, S16, T25, P7, S14] |
| Synchronized combination [S8, T20] |
| Possibility of last minute changes [P1, P2] |
| Integrated Solution [P1] |
| **Better resource utilization** |
| Reducing empty container routes [P4] |
| Minimal buffer time [S11] |
| Better utilization of resources [S8, P3, P6, P7] |
| **Environmental** |
| Environment friendly [S11, P3, S14] |
| CO2 decrease [P1, S12, S13, P7] |
| Sustainable [P1, S11, P3, S15, S16, P6, T21, S12, 28, S13, P7, S14] |
| Sustainable deployment of different mode [S8, P2, P3] |
| **Cost Reduction** |
| Reduce cost [P1, S11, P3, S16, P7, S14] |