



Article

Methodological Approaches to Evaluating Technological Chain Efficiency in the Silk Industry

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Abstract: In the article Uzbekistan silkworm on the network technological processes and work to release chain efficiency assessment issue research done In the analysis alive cocoon cultivation, raw silk work to produce, silk cotton wool, calavated silk thread, silk fabric, ready silk products, export composition and traditional and cluster system between comparative indicators together seeing released Results on the network again work and ready to the product passage opportunity increased, however fabric work output, export stability, crude silk exit methodology and product composition according to additional management indicators the necessity showed.

Keywords: Silk industry, technological chain, cluster system, added value, again performance, export composition, raw silk, ready-made product.

1. Introduction

Silk production Uzbekistan village farm and industry between to contact clearly expression which from networks is one of them. economic content only cocoon cultivation or raw silk work to release with is not limited. Network mulberry, silk worm seed, cocoon care, reception make, sort, raw silk to take, silk thread and fabric prepare, ready thing work output, internal and outside to the markets delivery like mutual related from stages consists of of these stages in any interruption appearance if, in the whole chain added value creation opportunity decreases.[1][2]

Last in years cluster approach in network through work to take out to coordination attention increased. Cluster system raw thing breeder, re worker, exporter and service indicator subjects one economic to the chain to tie in view But cluster effect in practice only the number of enterprises or general product volume with if measured, internal technological dependencies enough unopened remains. For example, alive cocoon volume growth positive result even though it is raw silk, fabric and ready to the product if not, economic of value big part network inside not saved.[3]

Silk production according to scientific in literature last in years two important direction increased. First direction silkworm stable agro-industry as interpretation to do with connected. Altman oath Farrell sericulture mulberry, worm cultivation and post-cocoon processes agro- industry that unites activity as evaluates. Theirs in the approach silkworm natural to the resource to lean on with together village population employment, biological from materials effective use and village farm with industry between contact reinforcement to the possibility owner[4]

Second direction silkworm products and additional product diversification to the issue directed. Jaiswal, Banerjee - Dube oath Mayookha sericin, fibroin, worm dome and other biological remains medicine, cosmetics, food appendages, animal feed, fertilizer and biomaterials work to release for separately value source to be possible shows. This

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conclusion silkworm efficiency only raw silk exit with not, but adjacent products and new markets with both tied to study the necessity means.[5]

El Salvador meat al. Brazilian sericulture for example roundabout bioeconomy opportunities analysis to do, to work internal currents in the output system inside holding stay additional value creation This is based on approach in silk production waste, approach products and technological losses as an economic resource to see possibility gives So, again work level and of losses decrease not only technological, but also economic efficiency indicator as both It is significant.[6]

Technological processes according to in research cleaner work to release and life cycle costs assessment issue both important place Yin meat al. silk thread work in production abbreviated and ecological in terms of cleaner directions energy consumption, labor density and material wasteful to reduce service to do shows. Wu meat al raw silk work to take out life cycle is ecological and economic assessment through learning, technological processes cost, resource consumption and ecological impact with together evaluation the necessity emphasizes.[7]

2025 in research silk industry roundabout to the economy transfer issue further more precisely was put. Hassan meat al. (2025) silk in the industry stable value chain practices analysis circularity, traceability and transparency, that is circulation, observation and openness principles work from taking out to the market was stages in management solution doer importance profession verb This is based on opinion Uzbekistan sericulture for both actual : as part of export ready product share increasingly product come exit, again work stage, quality standard and delivery to give discipline they become important.

International organizations materials both present the direction supports. European Parliamentary Research Service (2024) textile in the field digital product passport traceability, circularity and added to enhance transparency value which one in phase the creation to determine service to do shows. Textile Exchange is global textile industry and clothing supply standards in chains, assurance and traceability systems importance increasing that he is going emphasizes. So, in silk industry technological the chain assessment not just internal efficiency the issue is external to the markets exit requirements with both directly depends.[8]

Literature analysis that shows that sericulture according to last in research main attention product diversification, turnover economy, cleaner work release, life cycle costs and to observability directed. However Uzbekistan under the circumstances this approach cluster system results, export composition and traditional system with comparative assessment based on united research enough This article is not this space to fill directed.

2. Research methodology

The study covers the years 2021–2025. " Uzbek Industry " Association information, author calculations and international scientific from sources was used. The empirical base is alive cocoon, raw silk, silk cotton wool, calavated silk thread, silk fabric, ready silk products, export composition, re work level, raw silk exit coefficient, contract coverage, calculation term, losses and employment indicators cover will take.[9]

Methodological in terms of research five to the method relies on The first is dynamic analysis method is, then main product types years in the section is compared. The second is a chain analysis method is alive from a cocoon ready product and before export was the movement a complete system as sees The third is structural analysis method in export raw thing and ready product share change opens. The fourth is comparative analysis method is traditional and cluster system between the differences evaluates. The fifth one has an indicator assessment method is technological of the chain weak and strong points to determine service does.

Raw silk exit coefficient raw silk volume alive cocoon to the extent relatively calculation through was determined. Again work growth index and current year again work level previous year indicator with comparison based on was calculated. Again worked products share index raw silk, silk fluffy and wired silk thread like interval again worked products alive cocoon to the extent relatively assessment through was formed. This indicators absolute truth as not, but technological movement direction open giving analytical criteria as interpretation was done.[10]

In the article authorship approach technological the chain two in my layer to evaluate is based on In the physical layer natural movement of the product : cocoon, raw silk, silk thread, cloth and ready product sequence will be seen. Economical in my layer and of the product added for the price rotation : again work level, export composition, losses, contractual coverage, calculation speed and income indicators through is evaluated. This approach advantage is that it works to release volume automatic efficiency increase because reception does not, but from the resource what economic result received to determine strives.[11]

In analysis caution principled saved. Some indicators, in particular traditional and in the cluster system raw silk exit coefficient in the same methodology uncollected to be possible. That's why for in the article such numbers simple assessment for not, but calculation management and monitoring standards clarification the need indicator evidence as interpretation was done.[12]

3. Results And Discussion

Silk production products work to release on the chain changes first of all main product types in 2021 and 2025 condition through to see can This comparison on the network which one stages faster what is growing, which in stages and stability issue that it is stored shows.

Table 1. Silk production products work to release on a chain main of indicators change

Indicators	2021	2025	2025/2021, %
Live cocoons, tons	27,000	30 109.1	111.5
Raw silk, tons	2,400	3 200	133.3
Silk wool, tons	800	1,500	187.5
Calvary silk thread, tons	800	1,600	200.0
Silk cloth, thousand pog.m.	9.1	17.3	190.1
Silk carpet, piece	342	1,297	379.2
Ready silk products, thousand pieces	935.7	5,400.1	577.1
Again worked products share index	14.8	20.9	141.2

Source: author's calculations based on information from the "Uzbekipaksanoat" association.

Table 1 shows that alive While the volume of cocoons increased by 11.5%, the production of raw silk increased by 33.3%, silk roving by 87.5%, and spun silk yarn by 2 times. These figures indicate that, while the raw material base grew relatively slowly, growth was faster at the stages closer to processing. Thus, the economic performance of the industry began to be shaped not only by the increase in the volume of cocoons, but also by the transformation of this raw material into industrial products.

The 90.1 percent increase in silk production indicates that an important intermediate stage is emerging in the transition from raw silk to finished products. However, the growth rate of textile production after 2023 has slowed significantly. This situation shows that the stages of fabric, design, dyeing, sewing, standardization and certification must develop interdependently in order to expand the possibility of producing finished products.[13]

The volume of finished silk products increased from 935.7 thousand to 5400.1 thousand units. Such growth indicates that the industry has the opportunity to transition to high-value-added products. However, the slowdown in growth in finished products after a sharp jump in 2023 means that a one-time order or individual production expansion will require additional management to turn into a stable technological system. In this regard, not only volume is important in the production chain, but also the continuity of growth and the balance between products.[14]

Again worked products share the index increased from 14.8 to 20.9. This growth raw the thing again to work redirection that it has increased means. But index still high to the degree insufficient on a chain additional value creation opportunities complete to work that it didn't fall both shows. of the article main methodological conclusion from this point too come comes out : alive cocoon volume multiplication necessary, but enough not ; main issue this raw the thing which one to the extent ready product and to export value is in rotation.[15]

Table 2. Alive cocoon, raw silk and again work level between ratio

Years	Live cocoons, tons	Raw silk, tons	Recycling rate, %	Silk cloth, thousand pog.m.	Ready product, thousand grain	Raw silk output coefficient, %	Processing growth index
2021	27,000	2,400	55	9.1	935.7	8.89	100
2022	28,000	2,500	58	12.3	1,694.6	8.93	105.5
2023	29,000	2,800	61	16.8	5 201.1	9.66	105.2
2024	30,000	3 100	64	16.9	5,294.3	10.33	104.9
2025	30 109.1	3 200	67	17.3	5,400.1	10.63	104.7

Source: author's calculations based on information from the "Uzbekipaksanoat" association.

Table 2 raw from the thing The process of transition to industrial production is more clearly revealed. The raw silk yield coefficient increased from 8.89% to 10.63%. This indicates an improvement in the technological result in extracting raw silk from cocoons. However, it is not enough to interpret this indicator only as equipment efficiency, because it is also related to the worm breed, feed quality, rearing conditions, cocoon drying, storage, sorting and receiving processes. In this sense, raw silk yield is not a narrow technical indicator, but an indicator reflecting the level of overall technological adaptation.

Again work level from 55 percent to 67 percent It is raised. positive change on the network raw Internal re-arrangement of the material to work redirection that it has increased shows. But 67 percent degree so both hint says, raw of the thing one part still high valuable to the product without turning remains If the cocoon volume again and again work level enough to the extent If it doesn't grow, the network resource rich but value in creation limited in the case will remain.

In silk production of technology economic importance right here expression will be alive from a cocoon raw silk to take, raw from silk thread and fabric to prepare, then him/her ready to the product rotation in the process every one in phase new value is created. That's why for technological the chain in evaluation one to the indicator to lean on correct not. Raw silk exit, again work level, fabric work to release and ready product volume each other with connected in case when seen only real efficiency opens.

This The findings are also consistent with the circular value chain approach proposed by Hassan et al. (2025). They highlight the importance of technological innovation, waste management, resource flow monitoring, and transparent accounting for sustainability in the silk industry. The increase in the level of processing in Uzbekistan confirms this

opportunity, but without full tracking of product movements and losses, it is difficult to fully assess the economic impact of this opportunity.

Table 3. Silk production products export product types according to composition

Years	Total export, million US dollars.	Raw silk	Silk thread/yarn	Silk fabric	Ready-made silk products	Other products
2021	54.2	27.10	9.76	6.50	5.42	5.42
2022	96.2	44.25	19.24	13.47	10.58	8.66
2023	94.2	39.56	20.72	15.07	11.30	7.55
2024	52.6	19.99	12.62	9.47	6.84	3.68
2025	87.0	29.58	21.75	17.40	12.18	6.09

Source: author's calculations based on information from the "Uzbekipaksanoat" association.

Table 4. As part of exports ready product and raw thing share change

Years	Share of finished product, %	Raw material share, %	Export geography, number of countries	Content
2021	40	50	15	The proportion of raw silk is high, and the transition to finished products is at an initial level
2022	45	46	16	Export volume sharp increased, structural movement started
2023	50	42	19	The share of finished products and processed products has strengthened
2024	55	38	18	Total exports decreased, however structural adjective improving continue did
2025	59	34	20	Dependence on raw materials has decreased, market geography has expanded

Source: author's calculations based on information from the "Uzbekipaksanoat" association.

Export composition technological of the chain in the market the result shows. Total exports range from 54.2 million US dollars to 87.0 million US dollars increased, but this growth one flat not passed. In 2022–2023 high result record done in 2024 decline observed in 2025 and again recovery It was. situation silkworm products outside at the market demand, price, contract and to logistical changes sensitive that shows.

The main content total export in change not, but in its internal structure there will be an expression. Raw material share from 50 percent to 34 percent decreased. Ready product share and from 40 percent to 59 percent increased. This added of value higher to stages slimy what started means that raw silk in export still both noticeable to the place have So, the network raw to the thing from relying exit the process started, but this process complete completed because will not happen.

In 2024 a decrease in total exports in case ready product share on the rise continue what did separately to your attention worthy. This two the process together interpretation to do If the export value decreases, but ready product share if it exceeds, then structural adjective improved to be possible, but market size, price, sales channel or outside demand under the circumstances problem saved. On the contrary, the export value if it is too much, raw

thing share high if, currency income increased internally joined with value limited It will be. export performance for in assessment « how much sold?" question with together " which" product in appearance sold?" question both to be placed condition

Export geography from 15 countries to 20 countries expanded. This outside to the markets exit opportunity increased shows. But geography expansion does not automatically ensure efficiency. If new to the markets mainly raw silk or low added valuable products if released, economic fruit is limited. Therefore, export geography product types in the section assessment necessary. This approach European Parliamentary Research by Service (2024). in textile added value identification, traceability and increase transparency necessity about conclusions with both compatible.

Textile In Proceedings of Exchange (2025). global textile industry in chains standards, assurance and traceability systems becoming important going record Uzbekistan sericulture for this requirements ready silk products export in expansion further important. Because ready product in export product come output, raw thing source, again work stage, quality standard and delivery to give reliability buyer the decision determining to the factors It turns.

Table 5. Traditional and in a cluster system technological and economic of efficiency comparative analysis

Indicators	Unit of measurement	Traditional system	Cluster system	Difference (+/-)	Relative change, %
Cocoon productivity	kg/box	55	60.21	5.21	9.5
1 hectare of jute obtainable cocoon volume	kg / ha	500	557.50	57.50	11.5
Raw silk yield coefficient	%	13.50	10.63	-2.87	-21.3
The degree of cocoon processing	%	52	67	15	28.8
Losses in cocoon reception	%	6.50	3.20	-3.30	-50.8
Billing period	day	30	15	-15	-50.0
Scope of the Agreement	%	68	95	27	39.7
Share of export-oriented products	%	42	65	23	54.8
Share of finished product	%	26	48	22	84.6
Per householder / household average income	thousand sum	4 200	6 100	1,900	45.2
Employment coverage	person	305,000	1,427,900	1,122,900	368.2

Source: Data from the Uzbek Industry Association and the author's analytical comparative calculations.

Traditional and cluster system comparison of clustering technological and institutional fruit one how many on the way opens. Cocoon productivity in the cluster system is 60.21 kg/ box enough, this traditional to the system relatively 9.5 percent high From one hectare of jute obtainable cocoon volume also from 500 kg to 557.5 kg increased. This results food

base, agrotechnics, maintenance and reception in the processes coordination effect the existence shows.

Raw silk exit coefficient according to in the table cautious interpretation demand will be done. Traditional in the system this the indicator is 13.5 percent, 10.63 percent in the cluster system as given. This digital simple as a "cluster system " weak " to the conclusion take arrival correct First, two system according to information in the same methodology collected or not clarification it is necessary Second, raw silk exit type of cocoon, humidity, sorting standard, re work mode and workers to the qualification depend So this is it row assessment methodology standardization the need shows.

Again work level according to difference quite a bit exact: traditional 52 percent in the system, 67 percent in the cluster system. This raw the thing network inside holding stay and him/her high valuable to the product zoom in opportunity in cluster conditions that it has increased means Cocoon reception in doing losses from 6.5 percent to 3.2 percent reduced logistics, acceptance order and adjective control improved shows. Such losses in the table small like a number Although it seems raw thing general volume to account when taken their economic effect big will be.

Account book from 30 days to 15 days of the term reduction of the cluster system financial to circulate the effect shows. Cocoon grower or housewife own labor for faster payment if you get it, then next for the season preparation, food, labor and other expenses planning opportunity increases. Agreement from 68 percent to 95 percent of coverage increase and cluster participants between official connections that it has increased means In this respect, the cluster is technological system to be with together contractual and financial discipline system maybe.

For export directed product share from 42 percent to 65 percent, ready product share from 26 percent to 48 percent increased. This two indicator together cluster system when viewed not only work to take out organization reach, but to the market exit opportunities to expand both service what is doing It seems. However for export being released of the product composition, price, standard and market according to stability separately if not counted, general shares behind real economic fruit complete It won't open.

Homemaker or to the house correct coming average from 4.2 million soums to 6.1 million soums of income increase social result point from the point of view important In silk industry home economics village households in places income expansion, women and the youth to work attraction to do and seasonal employment economic to the result rotation the opportunity gives. But employment only by the number of people assessment enough not ; work duration, income level, labor productivity and ready to the product added contribution both separately indicator to be need.

Table 6. In silk industry technological chain efficiency assessment for offer being pushed criteria

Chain stage	The main evaluation criterion	Economic content	Significance for management decision
Food and cocoon base	1 hectare of land cocoon, box fertility	Raw material sufficiency and agronomic performance	Which one? in the area food and cultivation to strengthen shows
Raw silk to take	Raw silk exit coefficient, sorting quality	From the cocoon industry to the product passage fruit	Receiving, drying, sorting and silk solution technology evaluates
Aralyk again work	Silk wool, silk thread / kalava, cloth volume	Raw material high for the price approach	Which one? interval in phase strength lack of determines
Ready product	Ready things volume and share	Internal added of value growth	Design, standard, certificate and branding development the need shows
Export	Raw material and ready product share, number of markets	Market result and foreign exchange earnings quality	Export contents high valuable products in favor of to change help gives
Social result	Employment, homemaker income, calculation term	Cluster population to income effect	Labor interest and contractual discipline increases

Source : author by work is out.

Table 6 shows the methodological novelty of the article. summarized. This in approach every one indicator separately result as not, next to the stage impact indicator as a linking indicator interpretation will be done. For example, food base expansion cocoon productivity, cocoons quality raw silk to come out, raw silk and silk thread volume fabric and ready to the product, ready product and export income and population to income impact does.

Proposal being pushed approach in practice three to the question answer gives. The first question : raw thing base technological the chain enough to the extent does it provide Second question : raw thing which one in phase for the price is spinning and which one in phase value is disappearing ? Third Question : ready product and export growth population income, contract discipline and employment stability what impact is doing this ? to questions answer of the cluster system when found real efficiency It is visible.

This approach scientific in terms of so it is based on silk industry technological efficiency one on point not, in the whole chain is formed. Equipment update important, but it is food base, cocoon quality, acceptance discipline, again work power, design and market demand with if they don't unite, it's final economic result is limited. That's why in a cluster system for technological processes to evaluate simple work to release from statistics according to wider, added value and market to the result connected in a way organization verb to the goal suitable.

Analysis results that shows that Uzbekistan cluster system in sericulture contract scope, again work level, losses reduction, calculation period, for export directed product share and employment according to traditional to the system relatively noticeable to the advantages owner. With that together, raw silk exit coefficient and fabric work to release dynamics like separate indicators technological calculation clarification, product types according to separate monitoring and clusters in the section the information standardization the necessity shows.

4. Conclusion

Take visited research silkworm on the network technological processes efficiency only cocoon cultivation or raw silk work to release volume with assessment enough that it is not showed. of the network real economic result raw from the thing which to the extent silk yarn, fabric, ready-made product and export value harvest what is happening with is determined.

Working to release chain analysis alive cocoon volume relatively slowly grown although, raw silk, silk thread, cloth, carpet and ready in products higher growth observed showed. This on the network again work and product assortment expansion through added value creation opportunity that it has increased means. But fabric work to release and ready product in size growth of the steps stable absence technological the chain constant monitoring the need to the surface brings.

Export analysis total export volume that it has grown, but his/her dynamics one flat that it wasn't showed. Raw material from 50 percent to 34 percent decrease and ready product from 40 percent to 59 percent of its share increase positive structural is a shift. Thus together with a decrease in exports in 2024 ready product share increase with together market, logistics, standard and contract stability both reinforcement demand to be done shows.

Traditional and cluster system comparison of clustering main advantages again work level, losses reduce, contract coverage, calculation period, for export directed product share, ready product share and employment within the scope of expression what is happening showed. However raw silk exit coefficient Methodological inaccuracies in exists was for this indicator separately standardized calculation based on management necessary.

The article scientific novelty as in silk production technological chain efficiency assessment for " alive " cocoon — raw silk — silk thread / kalava - silk fabric — ready product — export — social result » sequence based two layered approach offer done In this approach, the physical product movement economic value movement with is connected. As a result, in a cluster system which one resource is sufficient at the stage, which in phase value is disappearing and which one in phase market opportunity strong that is more precisely is evaluated.

Operation point from the point of view silkworm in clusters technological management reinforcement for raw thing quality, raw silk exit, again work strength, fabric and ready product size, export composition, product standard, losses, contract scope and calculation the deadline only assessment in the system observation to the goal according to Then the cluster system only organizational form not, but added value, export and population income connecting as an economic mechanism It works.

REFERENCES

- [1] G. H. Altman and B. D. Farrell, "Sericulture as a sustainable agroindustry," *Cleaner and Circular Bioeconomy*, vol. 2, Art. no. 100011, 2022, doi: 10.1016/j.clcb.2022.100011.
- [2] European Parliamentary Research Service, *Digital Product Passport for the Textile Sector*. Brussels, Belgium: European Parliament, 2024.
- [3] R. Hassan, F. Acerbi, S. Terzi, and P. Rosa, "Transitioning the silk industry towards circularity: A thematic analysis of sustainable value chain practices," *Sustainable Production and Consumption*, vol. 56, pp. 94–111, 2025, doi: 10.1016/j.spc.2025.03.009.
- [4] K. K. Jaiswal, I. Banerjee-Dube, and V. P. Mayookha, "Recent trends in the development and diversification of sericulture natural products for innovative and sustainable applications," *Bioresource Technology Reports*, vol. 13, Art. no. 100614, 2021, doi: 10.1016/j.biteb.2020.100614.

- [5] R. Salvador *et al.*, "Circularity of Brazilian silk: Promoting a circular bioeconomy in the production of silk cocoons," *Journal of Environmental Management*, vol. 296, Art. no. 113373, 2021, doi: 10.1016/j.jenvman.2021.113373.
- [6] Textile Exchange, *2024 Annual Report*. Textile Exchange, 2025.
- [7] Z. Wu, W. Xu, X. Wu, and X. Ding, "Life cycle environmental and economic assessment of raw silk production in China," *Sustainable Production and Consumption*, vol. 55, pp. 11–23, 2025, doi: 10.1016/j.spc.2025.02.002.
- [8] R. Yin *et al.*, "Cleaner production of mulberry spun silk yarns via a shortened and gassing-free production route," *Journal of Cleaner Production*, vol. 278, Art. no. 123690, 2021, doi: 10.1016/j.jclepro.2020.123690.
- [9] "Uzbekipaksanoat" Association, *Data on the Silk Industry for 2021–2025*. Tashkent, Uzbekistan, 2026.
- [10] M. F. Astudillo, G. Thalwitz, and F. Vollrath, "Life cycle assessment of Indian silk," *Journal of Cleaner Production*, vol. 81, pp. 143–151, 2014, doi: 10.1016/j.jclepro.2014.06.007.
- [11] A. Gaviria, N. Jaramillo-Quiceno, A. Motta, and A. Restrepo-Osorio, "Silk wastes and autoclaved degumming as an alternative for a sustainable silk process," *Scientific Reports*, vol. 13, Art. no. 15296, 2023.
- [12] L. Darith, "Integrating circular practices in the silk sector for enhanced sustainability," *International Journal of Sericulture*, vol. 6, no. 1, pp. 1–7, 2025.
- [13] S. J. Khan *et al.*, "A review on life cycle assessment in silk textile industry," in *Green Materials and Sustainable Manufacturing*, 2024, pp. 243–252, doi: 10.1007/978-981-97-0910-6_20.
- [14] B. S. Manjunath, B. Tandon, M. R. S. Prakash, V. Mishra, and T. K. Dash, "Circular economy in silk industry," in *Science and Technology of Silkworm Sericin: Extractions, Modifications and Applications*. Amsterdam, The Netherlands: Elsevier, 2025, pp. 591–609, doi: 10.1016/B978-0-443-21736-4.00020-9.
- [15] C. Capuzzimati, V. Buzzi Franzoso, M. Sorlini, S. Corsi, and G. Bergna, "Valorisation of silk textile industry wastewater for sustainable agriculture: Life cycle assessment and life cycle costing of sericin biostimulant application in lettuce cultivation," *International Journal of Environmental Science and Development*, vol. 17, no. 1, pp. 39–47, 2026, doi: 10.18178/ijesd.2026.17.1.1562.